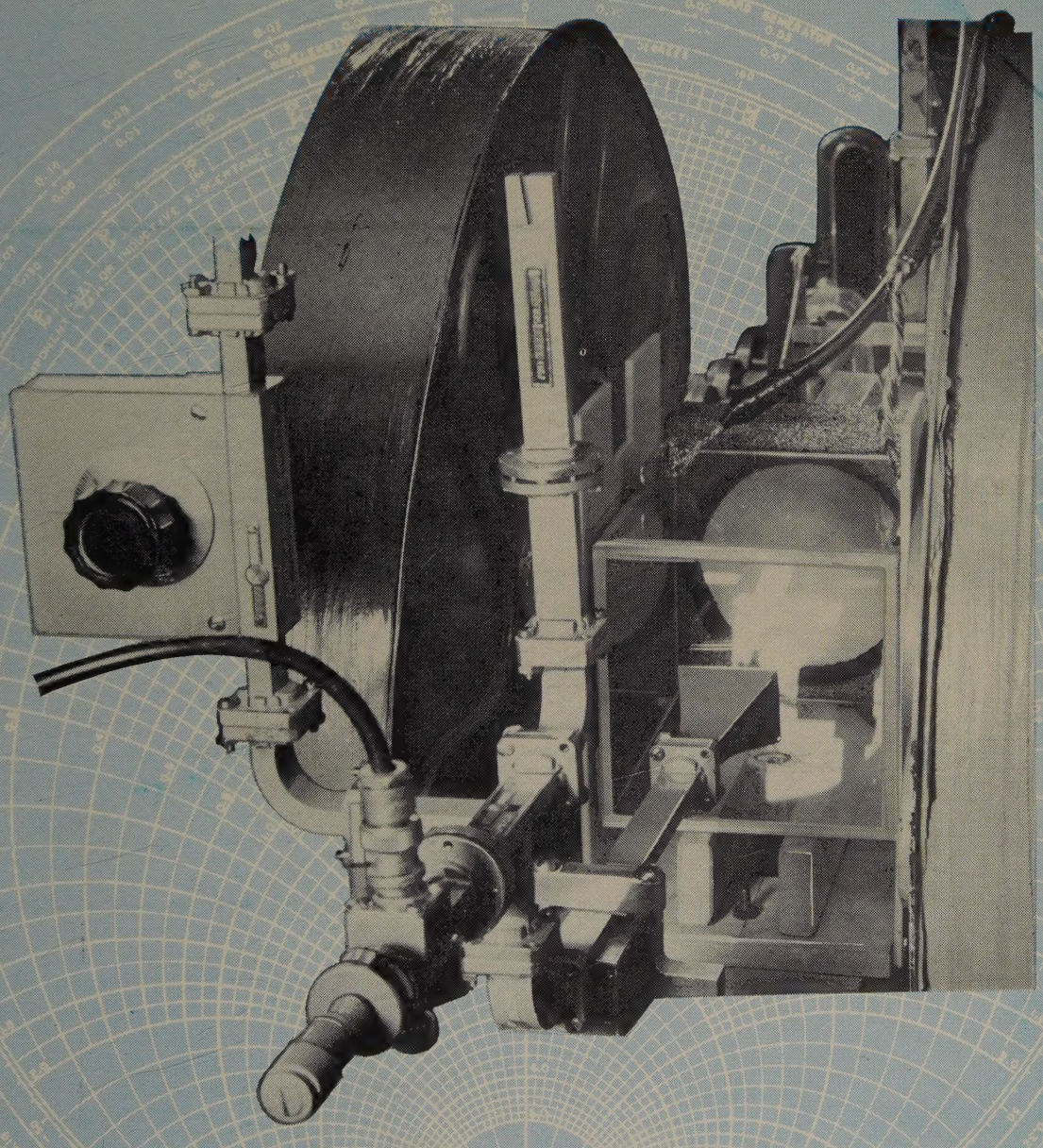
FEBRUARY 1959
VOL. 2 • NO. 2

- Whitmer — Ionized Media - I
- Rajcok and Wheeler — Ferrite Isolators
- Southworth — Using Smith Chart - II
- Airtron, Inc. — Company Profile

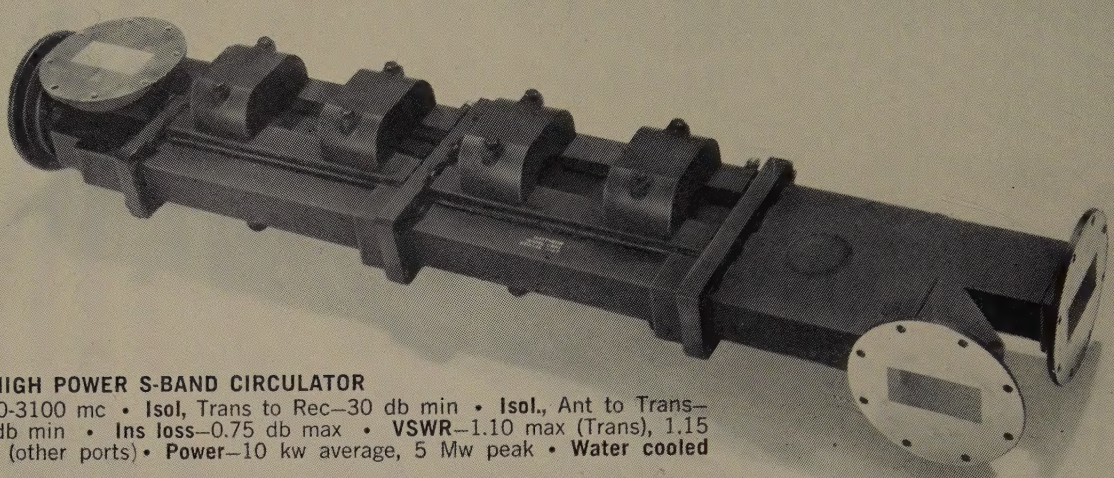
the microwave journal



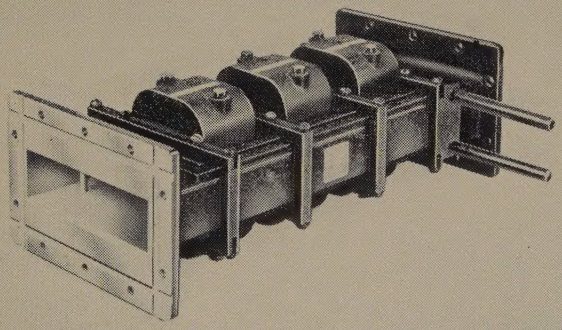
Microwave Electronics & Supply
8000 W. 51st St.,
Chicago 38, Ill.

NEXT ISSUE — MASERS AND PARAMETRIC AMPLIFIERS — IONIZED MEDIA - II
MASERS FOR RADIO ASTRONOMY

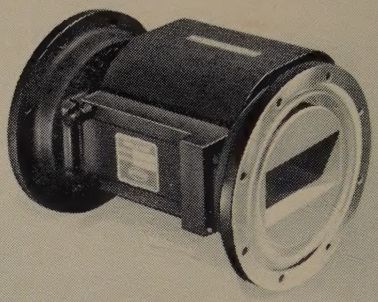
Recent Raytheon developments in microwave ferrite devices



1. HIGH POWER S-BAND CIRCULATOR
2600-3100 mc • **Isol,** Trans to Rec—30 db min • **Isol.,** Ant to Trans—20 db min • **Ins loss**—0.75 db max • **VSWR**—1.10 max (Trans), 1.15 max (other ports) • **Power**—10 kw average, 5 Mw peak • **Water cooled**



2. HIGH POWER L-BAND ISOLATOR
1250-1350 mc • **Isol.**—11 db min • **Ins loss**—0.55 db. max • **VSWR**—1.15 max • **Peak power**—3 Mw • **Av power**—2.5 kw (cooled); 1.0 kw (uncooled)



3. HIGH POWER S-BAND ISOLATOR
2750-3050 mc • **Isol**—10 db min • **Ins loss**—0.6 db max • **VSWR**—1.10 max • **Peak power**—3 Mw (pressurized) • **Av power**—3 kw (water-cooled)

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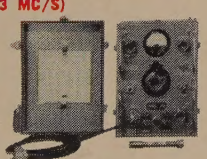

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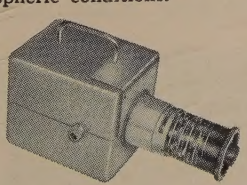

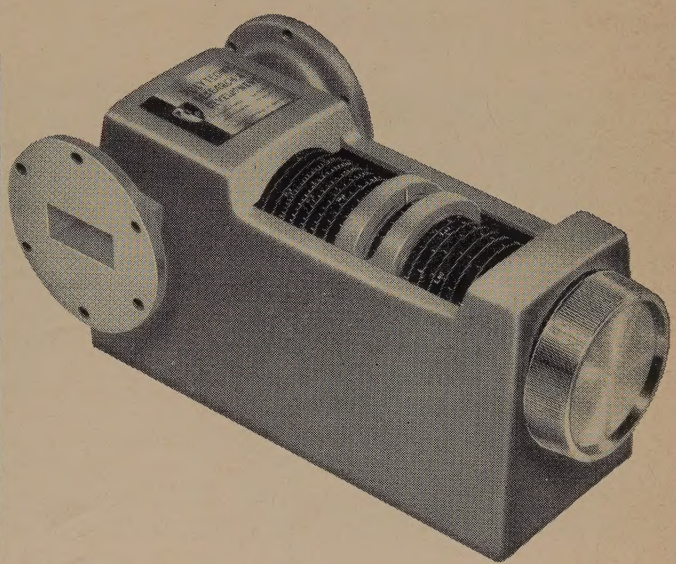

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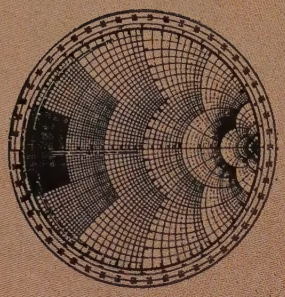

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COVER PICTURE

The picture on the cover is a laboratory set up for studying propagation through Ionized Media at Sylvania's Microwave Physics Laboratory.

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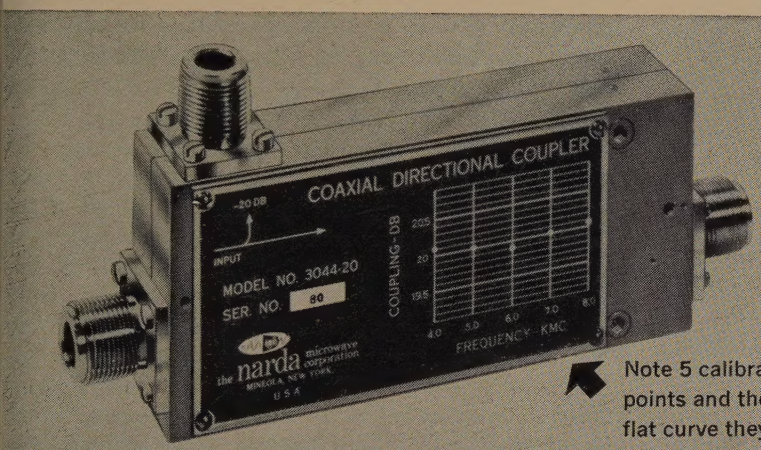

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950-2000	20	3042-20	1.1/1.2	20	1000	100	10	
2000-4000	20	3042-20	1.15/1.2	20	1000	200	10	$200
4000-8000	20	3044-20	1.2/1.25	17	1000	200	10	
7000-11,000	20	3045-20	1.25/1.3	15	1000	200	10	

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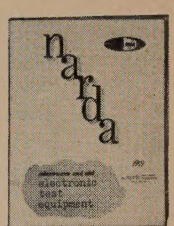

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THE CONSERVATION of ENGINEERING TALENT

by

H. A. FINKE, Gen. Mgr.
Polytechnic Research & Development Co., Inc.

THERE IS NO scarcity of publicly expressed concern about the present and future shortage of engineering and management personnel. The search becomes more and more intensive, both for administrators and engineering specialists. It is a first order of necessity that we use the engineers we have as effectively as possible.

I daresay nobody will dispute this logic, but I have observed that the natural economic force of short supply and huge demand triumphs over logic, even in an industry which requires the use of man's keenest intellectual prowess. The simple truth of the matter is that engineers are also human beings who will try to get the best possible jobs available, and they have every right to do so in a free society. Since management jobs are the plums in the pudding, management jobs they will seek — and get — whether or not they are qualified to manage. This results, far too often, in miscast managers and a permanent loss of potentially valuable specialists.

This situation is with us now and we must deal with it now, in terms of common sense. We must create balancing economic forces to enhance the value of engineering specialist jobs so as to attract those men whose talents lie in this direction. Only by equating the skilled specialist's job with the manager's job will we be able to effect more intelligent use of our manpower.

In the effort toward efficient manpower utilization the emphasis, hitherto, has been on ensuring that the engineer minimize his non-technical activities and spend a maximum of time at actual engineering. Very little, however, has been said about the importance of developing talented individuals along the lines of their greatest growth potential. The glittering pressures to which so many succumb — salary, title, supervisory responsibility — may ignore real professional aptitudes.

It is hardly profound to say that some engineers belong in systems design and others in theoretical research. Some belong in sales and others in production or development. Some belong in small companies and others in giant corporations. Some are natural managers and some are specialists. I do not contend that we are a doleful profession of square pegs in round holes, since each of us attempts, to some rational degree, an intelligent screening of our abilities. Our prospective employer, furthermore, is generally clever enough to avoid gross mesalliances — provided he is not too desperate. I do contend, however, that today the dominant criteria for job selection do not include objective self-analysis directed toward optimum use of one's abilities.

Many engineers base their choice of job on salary, supervisory responsibility, location, and general field of interest of the particular company involved. They will, it is true, inquire about the specific type of work to be done but, often, the interviewer senses that this is a perfunctory question, part of the proper stage setting necessary to make a good impression. Frequently, a man will settle for a higher salary, a better title and a few more people under him, granting but a casual glance to his specific future assignments. The almost universal desire of engineers to become administrators is, paradoxically, laudable and distressing. This desire is so common that he who does not aspire to supervisory responsibility risks being classified as an ambitionless psychotic. Supervisory responsibility is second only to salary as an object of blind worship by the unqualified. Salary and supervisory responsibility — how many miscast managers and how many miscast specialists worship at their shrines?

Unfortunately, the fact that the shortage of managers is at least as great as the shortage of specialists provides unprecedented opportunities for the unqualified. Clearly some of us are better equipped to be supervisors than others. Equally, some of us are better equipped to do the direct engineering work of the specialist. Each has his own forte. In a competitive society that favors the supervisor can we expect other than a surging strain to attain a supervisory position? If we do not reward the elite specialist in equal measure, for equal contribution, we drive the capable, working level engineer to seek what he may well be unsuited for — administration.

The pressure for salary and prestige, via administration affects our young engineers at an early stage in their careers. Because of the technical manpower shortage many of them attain supervisory responsibility without having served a reasonable apprentice period, during which they might acquire a rounded knowledge of the working level problems. They do not have a chance to ripen on the vine, blend their theoretical knowledge with the exasperating reality of work at the bench. Without practical experience they are ill-prepared to cope with the impossible, the improbable, the impractical plus all the other imps that bedevil engineering projects.

It is unfortunate that so many young men do not take the time to build a solid professional background. There is a golden time in a man's professional life for advanced study, for writing papers, for all the other career-enriching activities. The man who "gets there too soon" may well be plagued by lack of this background in years to come.

I can see only one way of offsetting these pressures. Management must learn to give comparable rewards to the maturing specialist, in terms of money and prestige so as to encourage him to an objective evaluation of the future use of his best abilities. Were there not so marked

HERBERT A. FINKE was graduated from MIT in 1939 with a B.E.E. He received the M.E.E. degree from Brooklyn Polytechnic Institute in 1948. During the period 1939-1941 Herbert Finke was associated with the United Aircraft Corporation, where he served as administrative assistant to the chief engineer.

In 1941, he joined the RCA Princeton Laboratories as research engineer on vacuum tube design. He invented the coaxial line noise diode and contributed to the development of electron beam deflection devices. From 1944-1945 he was assigned to the RCA Laboratories in New York City, where he participated in flight testing of LORAN and SHORAN.

Mr. Finke transferred to PRD as Director of Engineering in 1946. Under his aegis, PRD pioneered industrial microwave measurements and opened up the field of commercial microwave test equipment and components. He spearheaded the development of the largest line of microwave test equipment. In March 1957 he was named general manager. Since his appointment, PRD has almost doubled its volume of business and produced the first portable, completely sealed MASER.

Herb Finke is a member of Sigma Xi, Pi Mu Epsilon, the AMA and the IRE. He was active on the PGAP and Waveguide and Antennas Committees and has published papers and holds patents in the microwave field.

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difference in reward to the specialist, as compared to e manager, the natural gravitation of an individual ward employment of his best talents would operate to e greater well being of both the individual and the dustry.

We must also take a long look at the different qualifica-ns necessary for different professional fields. Here, too, e find the same fetishes misdirecting our manpower. 'hat does it take to be a successful microwave engineer compared to a successful computer engineer? Both re-ire about the same education. Both require considerable cility with mathematics and physics, and ability to think abstract terms. However, the microwave engineer, ex-pt for the pure theoretician, requires a better appreciа-n of mechanical engineering and shop practice and, de-rably, should have some degree of manual ability. When young graduate leaves school and is offered alternatives either the computer or microwave field does he ques-n himself as to his optimum fitness? I doubt it. He ill respond to the job that appears to be a super highway fortune, often ignoring aptitude and opportunity for ofessional development. I am surprised at how little im-rtance the modern engineer ascribes to the professional vironment in which he will find himself. I believe, rongly, that association with top-level engineers can ac-lerate a young man's progress to an enormous degree. et, currently, this factor seems to be of small moment.

A corresponding use of false standards taints the engi-er's evaluation of his aptitudes for sales, production, de-gn, development or research. The personal decision in-lved here is of great importance to the individual. Our hools and our personnel interviewers try to describe the fferent requirements of each professional area, but in hat distorted mirrors do we see ourselves? Many gradu-s pick research because of some glamorous association their day-dreams. Many pick sales because of the allur-g salaries that sales people are reputed to earn. Very v pick production, although some of the most rewarding portunities exist here, particularly in the development of nagement ability. We all smile at the worthy little man who buys skin-tight pants because they are breath-ing on Marlene Dietrich. How many of us are equally nd?

Similar distorted concepts are applied to the question of "where to work" — a large company or a small one. Here again I believe different talents are called for, but these differences are more obscure and difficult to evaluate. Many people will say, in a vague and meaningless way, that there are "greater opportunities" in a small company than in a large organization. One might ask — opportunities for what?

My opinion is that the opportunities for technical development do not depend on the size but, rather, on the vitality of viewpoint of an organization. On the other hand, opportunities for administrative maturing are related to the size of a company because of inherent operating differences.

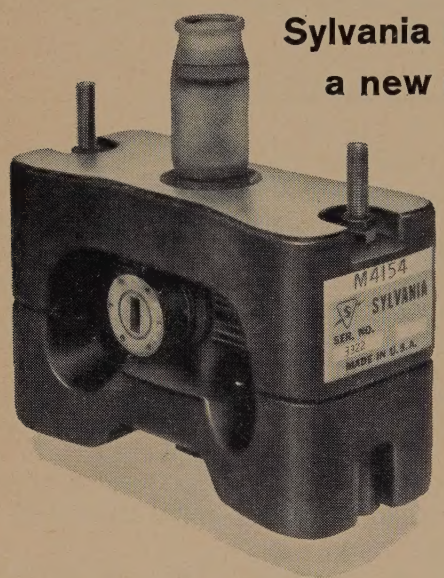
Small companies generally work with the smaller projects. A typical project, in a large company, may require fifty engineers. A typical project, in a small company, may require one or two engineers. Inevitably, this offers more broadening managerial experience to the small company lower level personnel. Then, too, there is greater individual stress both cost-wise and time-wise in the smaller company, and the engineer must be geared to respond to these urgencies at a much earlier stage in his professional career.

To summarize, I maintain that engineers are worshipping more and more only the fashionable idols of money, title and supervision. All of us are entitled to seek personal fulfillment, comfortable living and reasonable security, but there should be many roads to these goals, not only the single path of administration, supervision, etc. It is the responsibility of management to evaluate the inequities its policies create so that an engineer's best rewards will, in the long run, come from an honest use of his best abilities. There must be greater equalization of compensation. Only by this equalization will engineers be willing to correctly and objectively evaluate themselves in pursuing their professional careers.

If you have real ability in any specialization, you may well be able to display it to better advantage in your own company than in a new one. Your company, in turn, must learn to reward the able supervisor and the able specialist on a competitive basis. Unless the present mad scramble toward misuse of your best talents is arrested, the engineering industry will fast plummet into mediocrity.

MICROWAVE AND SPECIAL TUBE NEWS from SYLVANIA

NEW DESIGNS ADVANCE MAGNETRON RELIABILITY



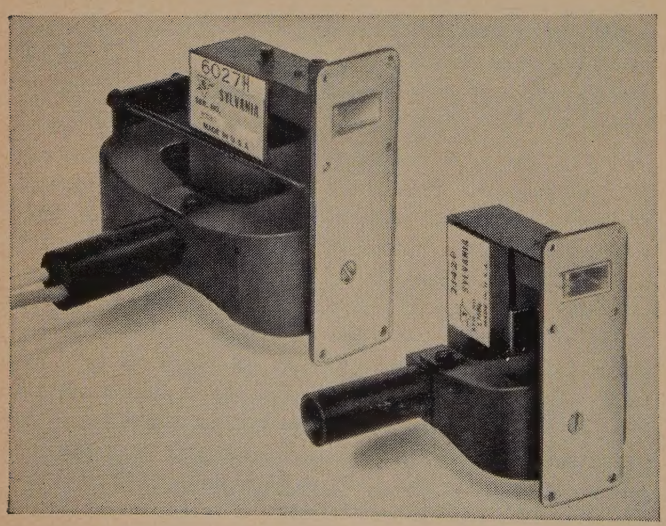
Sylvania microwave scientists and engineers create a new magnetron for airborne radar applications

Out of the microwave research and development laboratories of Sylvania's Special Tube Operations comes a new magnetron, type M4154, with advanced reliability features.

Through new improvements in cathode ruggedization and high pressure windows, the new K band magnetron meets the tough reliability requirements of today's air-borne military equipment. It can operate under 30 g at 20 to 2000 cps. It has a peak power output of 20 KW.

The new type M4154 is adaptable to either high or low altitude applications and easily meets and surpasses current missile vibration and shock requirements.

New developments in ruggedization of X-band fixed frequency magnetrons to meet airborne radar requirements



Two new magnetrons, Type 2J42B and Type 6027H offer important improvements over their basic types, where ruggedization is essential in commercial and military radar. The 2J42B adds superior ruggedness to the already outstanding high altitude performance of the 2J42H. It is particularly adaptable to ruggedized military air-borne applications. Type 6027H is also ruggedized for severe environments and is suitable for high altitude applications. For commercial and ground equipment, type 6027 is also available.

Both new types perform under 5 g at 10 to 500 cps with less than 3 mc. shift in frequency output and less than ± .5 mc. frequency modulation. They easily withstand 50 g shock for 4 ms. and are rated for top performance up to an altitude of 60,000 feet.

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Model No.	27-BW	27-CW	27-DW
Type of Resonator	TE_{101} mode rectangular	TE_{101} mode rectangular	TE_{101} mode rectangular
Tuning Range	2700-3150 MCS	2700-2950 MCS	2700-2900 MCS
3 db Bandwidth	4.5-6.5 MCS	4.5-5.5 MCS	4.5-5.5 MCS
Max 30 db Bandwidth	36 MCS	18 MCS	13 MCS
Max Insertion Loss	.9 db	1.3 db	1.8 db
Price	$400.00	$535.00	$670.00
Model No.	27-BC	27-CC	27-DC
Type of Resonant Cavity	$\lambda/4$ coax	$\lambda/4$ coax	$\lambda/4$ coax
Tuning Range	2700-3200 MCS	2700-3100 MCS	2700-2950 MCS
3 db Bandwidth	8-11 MCS	8-10 MCS	8-9 MCS
Max 30 db Bandwidth	60 MCS	32MCS	21 MCS
Max Insertion Loss	1.6 db	2.4 db	3.2 db
Price	$350.00	$475.00	$600.00

C BAND FILTERS

Characteristics	Two (2) Section Resonator	Three (3) Section Resonator	Four (4) Section Resonator
Model No.	54-BC	54-CC	54-DC
Type of Resonator	$\lambda/4$ coax	$\lambda/4$ coax	$\lambda/4$ coax
Tuning Range	5400-5950 MCS	5400-5950 MCS	5400-5750 MCS
3 db Bandwidth	8-11 MCS	8-10 MCS	8-9 MCS
Max 30 db Bandwidth	60 MCS	32 MCS	21 MCS
Max Insertion Loss	2 db	3 db	4 db
Price	$360.00	$485.00	$610.00

L BAND FILTERS

Characteristics	Two (2) Section Resonator	Three (3) Section Resonator	Four (4) Section Resonator
Model No.	96-BC	96-CC	96-DC
Type of Resonant Cavity	$\lambda/4$ coax	$\lambda/4$ coax	$\lambda/4$ coax
Tuning Range	960-1150 MCS	960-1100MCS	960-1050 MCS
3 db Bandwidth	8-11 MCS	8-10 MCS	8-9 MCS
Max 30 db Bandwidth	60 MCS	32 MCS	21 MCS
Max Insertion Loss	1.2 db	1.8 db	2.5 db
Price	$370.00	$495.00	$620.00

X BAND FILTERS

Characteristics	Two (2) Section Resonator	Three (3) Section Resonator	Four (4) Section Resonator
Model No.	75-BW	75-CW	75-DW
Type of Resonant Cavity	TE_{111} mode cylindrical	TE_{111} mode cylindrical	TE_{111} mode cylindrical
Tuning Range	7500-8500 MCS	7500-8250 MCS	7500-8000 MCS
3 db Bandwidth	8-11 MCS	8-10 MCS	8-9 MCS
Max 30 db Bandwidth	60 MCS	32 MCS	21 MCS
Max Insertion Loss	1.5 db	2.5 db	3.5 db
Price	$475.00	$625.00	$775.00
Model No.	85-BW	85-CW	85-DW
Type of Resonant Cavity	TE_{111} mode cylindrical	TE_{111} mode cylindrical	TE_{111} mode cylindrical
Tuning Range	8500-9600 MCS	8500-9300 MCS	8500-9000 MCS
3 db Bandwidth	8-11 MCS	8-10 MCS	8-9 MCS
Max 30 db Bandwidth	60 MCS	32 MCS	21 MCS
Max Insertion Loss	1.5 db	2.5 db	3.5 db
Price	$475.00	$625.00	$775.00

All of the above filters have Max VSWR of 1.5, and either a single shaft or counter dial for Tuning Control. Depending upon mode of operation, units are supplied with either Type N Connectors or Waveguide flanges.

DELIVERY IN 90 DAYS

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VARACTORS NOW!

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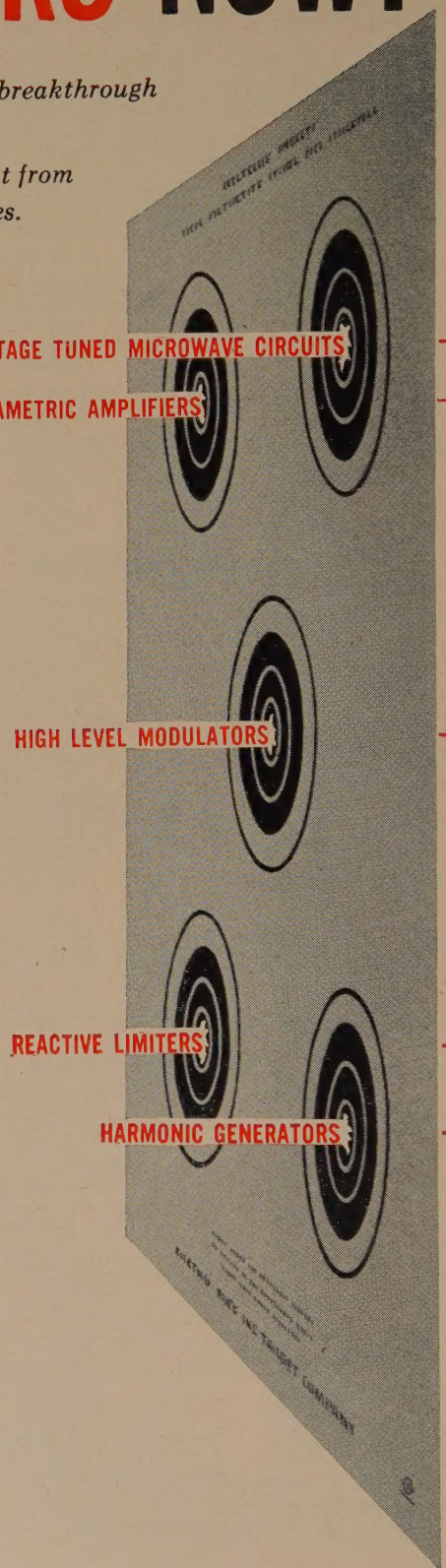
TODAY . . . *a production fact from Microwave Associates.*



This Microwave Associates varactor is a diffused silicon PN junction diode designed to be a variable capacitance with low loss at high frequencies. The unit complies with MIL-E-1 outline 7-1 for cartridge type crystal rectifiers and will fit most standard crystal holders.

In the standard form, the pin end of the diode is connected to P-type material on the top of a small "mesa" and the N-side of the silicon element is connected to the base. Reverse polarity units are also available. Mechanically reversible units in both polarities may be ordered but the single-ended units are generally recommended because they insure placement in holders with the proper end in contact with a heat sink.

TYPE	CUT OFF FREQUENCY (kMc)	CAPACITY AT ZERO BIAS ($\mu\mu$f)
MA-460A	20	8
MA-460B	30	6
MA-460C	40	4
MA-460D	50	4
MA-460E	60	3

VOLTAGE TUNED MICROWAVE CIRCUITS

The high Q of the varactor at microwave frequencies and its voltage variable capacitance provide excellent qualities for use in circuits as AFC, voltage variable filter networks, tuned microwave oscillators.

PARAMETRIC AMPLIFIERS

The varactor used in very simple circuits requiring no refrigeration has demonstrated low noise, high gain performance from 1 to 6000 mc. Noise figures of approximately 1 db at UHF and 5 db at 6000 mc. are typical. We believe the varactor will be the component of choice for receiver inputs from 30 to 6000 mc.

HIGH-LEVEL MODULATORS

For the difficult problem of imposing VHF and UHF intelligence on a microwave carrier the varactor is a top performer. The varactor accomplishes the mixing function with signal gain in the side bands as opposed to present low efficiency techniques.

REACTIVE LIMITERS

The varactor has been used as a passive reactive limiter at UHF frequencies. It is believed that the varactor will be an ideal "receiver protector" as an adjunct to present UHF radar duplexing systems.

HARMONIC GENERATORS

The unique properties of the varactor provide highly efficient harmonic generation. Useful harmonics have been generated up to 100 kMc. With inputs at VHF, UHF and lower microwave frequencies, conversion losses of considerably less than 1 db per harmonic have been observed. The varactor driven by transistor or tube oscillators appears very promising as a signal source in the microwave region.

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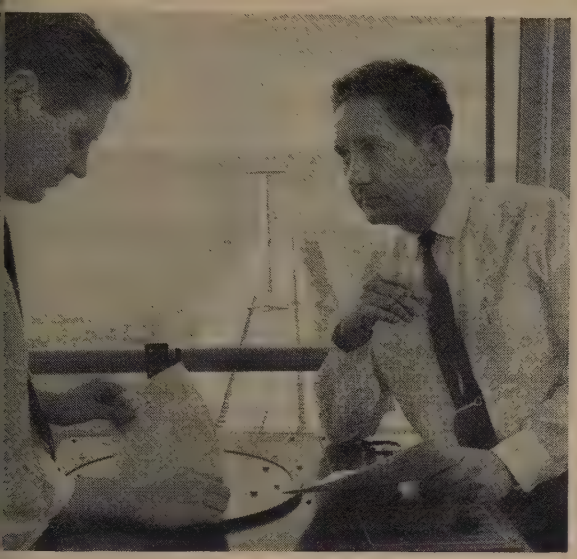
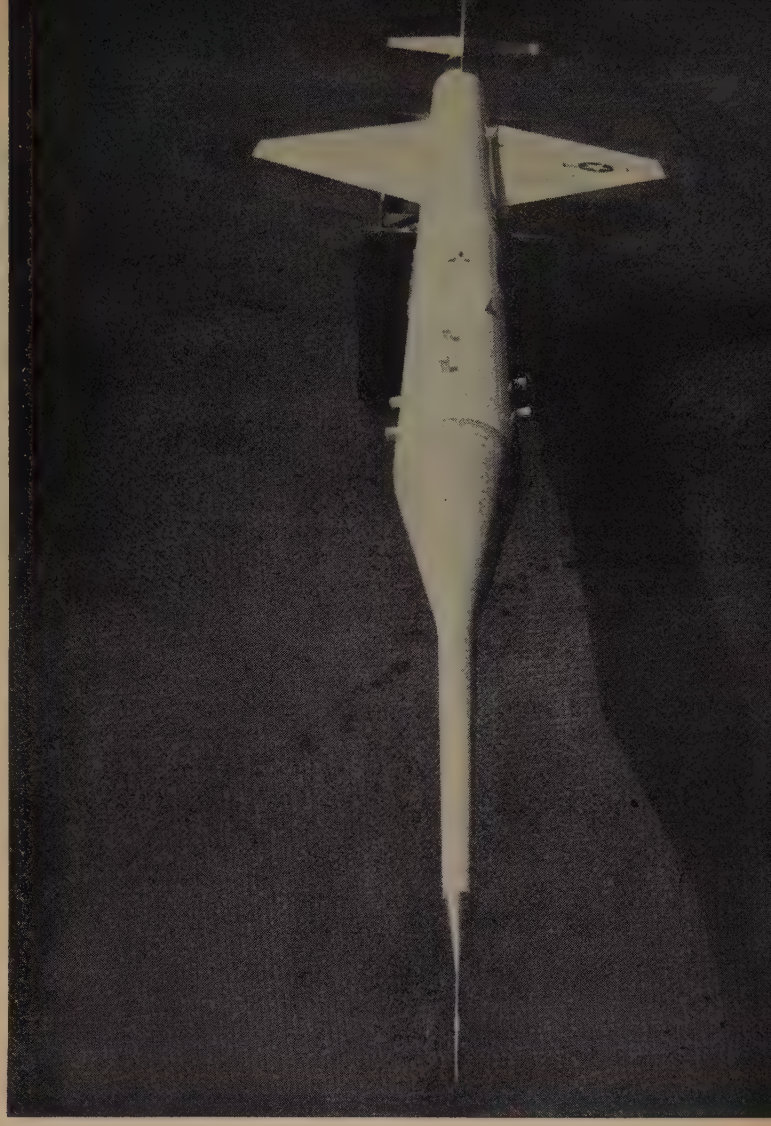
CIRCLE READER SERVICE CARD 5

EXPANDING THE FRONTIERS OF SPACE TECHNOLOGY

. Antenna-Telemetry



Studying results of antenna pattern measurements — part of the activity of the Space Communications laboratory.



Lockheed Q-5 target missile features telemetry that registers miss-distance and theoretical hits in testing accuracy of other missiles.

Lockheed maintains extensive research capabilities for the development antennas and telemetering systems and spacecraft applications.

Laboratory studies in antennas and electromagnetic propagation include application of solid state materials to microwave transmission line components; the design of antennas to survive the rigors of space flight; t effects of space on radio signals and radar detection; and the scattering from missile shapes and space vehicles. Research is also being conducted the application of ferrites and MASERS; on problems of radio transmissio between space vehicles and Earth, re-entry scattering and diffraction by man-made objects and ionized gases; and development of antennas for da link systems between satellites and ground stations.

Telemetering has been brought to a high degree of successful application in the integration of circuits and components into high-performance syste A completely sub-miniaturized FM-FM system has been developed, alon with a complete PAM-FM system characterized by highly efficient band- utilization, low power consumption and economy of size and weight. Thi represents a significant achievement in the field of high capacity teleme

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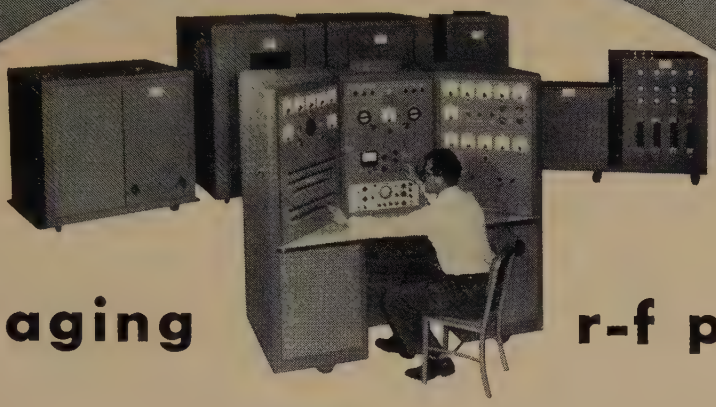
HOW LEVINTHAL CAN HELP



packaging r-f power

This array of units is the Levinthal Model 221M, a flexible system for generating and handling r-f power. Equipped with various klystrons, it serves such purposes as the testing of microwave components, powering experimental radar transmitters, or driving accelerators. It is also an ideal and complete facility for testing high-power pulsed microwave tubes.

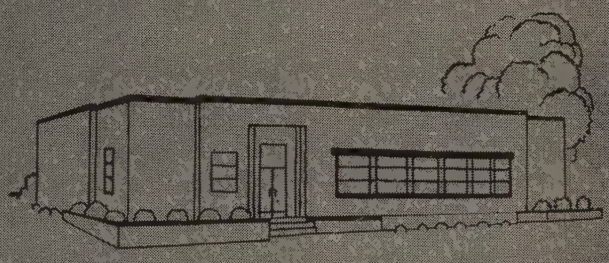
Using the Litton L3035, it delivers 3 megawatts in L band. With the L3250, it delivers 10 megawatts. Driving the Varian VA87, the 221M gives 1.3 megawatts in the S band, while use of the VA820 results in 5 megawatts peak and 10 kw average. The equipment is also suitable for operation with the classified Sperry SAC42 klystron.

As shown, the 221M includes an r-f magnetron driver unit and power supply, a modulator and power supply, trigger generator, field exciter, tank assembly, and oil and water cooling. A master console contains all equipment necessary to operate, control, sequence, and monitor the complete system.

Ask our representative for details or enlist our background & facilities in solving YOUR particular r-f problems.

Specialists in the unusual, Levinthal engineers comprise a highly qualified staff for providing solutions to the most difficult r-f power-handling problems.

Among the transmitters, modulators, power supplies, and accessories for radar, communications, and tube development which have already been produced, there may be units suitable for the solution of your problems. Let us send you a descriptive folder on these or discuss with you the design, development, and production of specialized equipment for your particular needs.



LEVINTHAL ELECTRONIC PRODUCTS, INC.

STANFORD INDUSTRIAL PARK PALO ALTO 4, CALIFORNIA

EQUIPMENT DIVISION

Since the start of "the microwave journal," one of the problems that is continually brought to our attention is the need for better standardization of frequency nomenclature in the industry.

In the second issue of the "journal," Bill Bourke of Narda pointed out the lack of standardization even between the four major microwave instrument manufacturers.

The problem is not earth shaking in its importance nor is it of great potential danger. The very lack of standard nomenclature keeps us alert for exact definitions wherever necessary. On the other hand, it is somewhat untidy. There is the everlasting need to spell out in detail the precise frequency range in megacycles.

Various companies adopt their own nomenclature. Most of them chose a coding system based partly on history and partly on convenience. We can recall at least one heroic instance where a company actually tried to coordinate the entire industry into one system of frequency coding.

There was a time when frequency coding was simple. In the microwave region the two bands of major interest were the so-called "S" and "X" bands. Now, however, between 1,000 and 90,000 megacycles there are many different waveguide sizes overlapped by the latest frequency groupings in terms of octave bandwidths. Up to the present time frequency nomenclature has usually been in terms of waveguide sizes. Soon new sets of frequency nomenclatures are apt to appear in terms of octave bandwidths.

Many groups have attempted to devise a universal coding system, but it appears that they met with only minor success. This may be traced in part to insufficient or improper publicity.

We would be interested to hear from people regarding this situation. If it appears worthwhile, we will summarize the comments and suggestions in an early issue of the "journal."

Our next issue is an important one on two counts. First, it is the I.R.E. National Convention Issue. Second, it was just one year ago next March that we announced our intention to publish "the microwave journal." A great deal of water has gone over the dam since that announcement. Some changes in the scope and activities of this publication have also resulted. We hope that in the year to come the "journal" will truly become a forum for the industry and will meet the ever-increasing need of improving the means of communication for both the engineers and the business people associated with this group.

In line with our increased scope of activity, we are issuing the call for papers. The monthly publishing cycle will allow us to use more material, and we are inviting all potential participants to submit their material. Our Associate, Mr. Gershon Wheeler, has asked us to notify those wishing to submit material in the West Coast area, that all papers in the western region be sent to "the microwave journal," P.O. Box 1134, Palo Alto, California.

Featured in our March issue will be a paper on Radio Astronomy by Dr. Harold I. Ewen, a paper on Parametric Amplifiers by Dr. Hubert Heffner, Part II of R. F. Whitmer's paper on "Principles of Microwave Interaction with Ionized Media." Seymour Cohn, one of our Associate Editors, has prepared an especially interesting and pertinent item entitled "The Noise-Figure Muddle." The Company Profile will be the first part of a two-part story on Raytheon, and Paul Odessey will supply a provocative business editorial.

Theodore S. Saad

Letters to the Editor

EDITOR
the microwave journal
160 Warren Street
Boston 19, Massachusetts
Dear Sir:

In order to keep the record straigh I feel I should point out a significan error in Mr. From's article on *Th Maser.* The first solid state maser t be operated was designed and teste at Bell Telephone Laboratories in th fall of 1956 and reported in the artic by Scovil, Feher, and Seidel, "Opera tion of a Solid State Maser," Phys. Re 105, p. 762L, Jan. 15, 1957.

Mr. From's error in attributin this first operation to the Lincol Laboratories probably arose as a re sult of a mistake in one of his ref erences. The article by A. L. Mc Whorter, J. W. Meyer, and P. D Strum on "Noise Temperature Mea urements on a Solid State Maser" ap peared in Phys. Rev. 108, p. 1642 Dec. 15, 1957, and not in 1956 as re ported in Mr. From's Bibliography.

Sincerely,

R. C. FLETCHER
Director, Solid Sta Device Developme

• ● •

The Editor
the microwave journal
160 Warren Street
Boston 19, Massachusetts
Dear Mr. Saad:

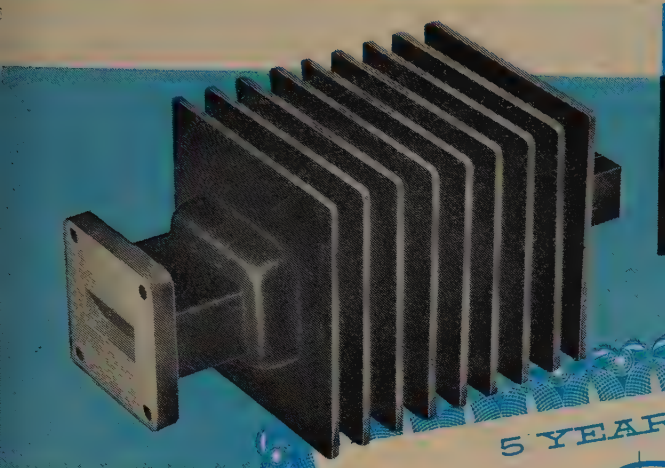
I appreciate the comments concern ing the section on history in my artic "The Maser" which was published i the November/December issue of th Journal. In retrospect, it is clear no that the title should have been "Th Three or More Level Solid State Mas Amplifier." The content of the artic conveys this but it was not stated e plicitly and thus was an oversight o my part.

With regard to Dr. Fletcher's no and in lieu of my omitting it as footnote, I should like to submit t following:

(*Continued on page 1*

for the First Time ...

GUARANTEED PERFORMANCE



4063 VHP* DUMMY LOADS

MODEL X4063

Equivalent to Jan DA-

The Bogart Model 4063 S Loads has evolved from a nee very high power dummy loads f tory use. Originally developed for Control Instrument Group, **the 4 time, the only family of high that have been approved b agencies. These units have be fied in accordance with specific and MIL-T-945A.** Previously, the won wide acceptance by service br R-F silence during tuning and mainte tenance and standard test conditions. with the highest power radar systems, are lightweight, compact, resistant t tion and intended to last at least the li with which they will be used. Reduced

Dummy Load requirements refer to Bogart

*PATENT PENDING

5 YEARS Warranted Performance

The Bogart Model 4063 Series of VHP Dummy Loads are warranted to maintain specified electrical characteristics for 5 years, when operated in accordance with the listed specifications.

Repair or replacement of any part proved defective in material or workmanship will be made at any time within 5 years from date of purchase.

This warranty will not apply to any such part which has been subject to any accident, abuse, misapplication or misuse.

Our obligation is limited to repair or replacement and we shall not be liable in any manner beyond this.

Model No.	Equivalent JAN Nomenclature	Frequency Range (KMC/S)	Max. Peak ‡ Power (Mega-Watts)	Average Power (Watts)	Maximum VSWR	Approx. Length (Inches)	Width (Inches)	Height (Inches)	Approx. Weight (Lbs.)	Waveguide AN Type
L4063	DA-147/U	1.12-1.70	17.2	6000	1.15	33	9	11½	60	RG-103/U
R4063	Pending	1.70-2.60	6.0	5000	1.10	21½	6½	8½	20	RG-105/U
S4063	DA-145/U	2.60-3.95	3.2 *	4500	1.10	14	5	6½	9	RG-75/U
A4063	Pending	3.30-4.90	2.1 *	2200	1.10	13	5½	6½	8	WR229†
H4063	DA-149/U	3.95-5.85	1.3 *	2000	1.10	9½	3½	4	5	RG-95/U
C4063	DA-144/U	5.85-8.20	0.71*	1000	1.10	8	3	4	2½	RG-106/U
B4063	DA-148/U	7.05-10.0	0.46	600	1.10	6½	2½	3	1	RG-68/U
X4063	DA-146/U	8.20-12.4	0.29	500	1.10	6	2½	2½	1	RG-67/U
KU4063	DA-159/U	12.4-18.0	0.16	250	1.15	4	2½	2½	½	RG-107/U**
K4063	DA-160/U	18.0-26.5	0.058	150	1.15	4	2½	2½	½	RG-121/U
KA4063	DA-158/U	26.5-40.0	0.031	75	1.15	4	2	2	½	RG-96/U**

*"These peak powers apply in .001 duty cycle applications." †RETMA DESIGNATION **ALUMINUM EQUIVALENT

‡"Peak powers are warranted at thirty (30) PSIG pressurization specification."

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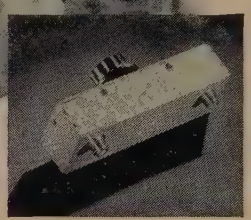
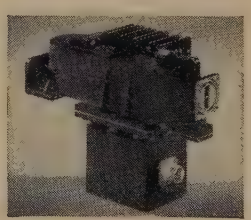


COAXIAL VARIABLE ATTENUATOR
Frequency Range-2670-2930 mc
Attenuation—25 db at 1.75 VSWR



HIGH POWER VARIABLE ATTENUATOR
Power Level—300 kw peak for 8.5-9.6 Kmc
Attenuation—.1-40 db at 1.15 VSWR

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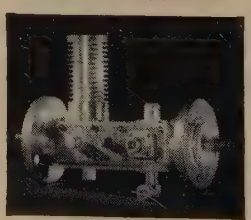
VSWR-1.06 maximum
Isolation-100 db minimum



COAXIAL DIRECTIONAL COUPLER
Coupling Values—20 to 50 db
Directivity—greater than 30 db

PRECISION IS PREMIER

PREMIER INSTRUMENT CORP.
33 New Broad Street, Port Chester, N. Y.
THE WAVEGUIDE HOUSE

CIRCLE READER SERVICE CARD 8

Letters to the Editor

(*Continued from page 12*)

1. That Bell Laboratories be credited with having operated the first Maser oscillator and thus proved that a Maser amplifier could be designed.
2. That Lincoln Laboratory be credited with having designed and operated the first Maser amplifier giving the amplifier electrical characteristics as well as oscillator characteristics which are required to well-define such devices.

In other respects, it would have been desirable to have had available R. W. DeGrasse's article "Slow-Wave Structures for Unilateral Solid-State Maser Amplifiers" in time for incorporation into my article. It is highly recommended.

I conclude this by remarking on the calculation of the excess noise contributed by lossy waveguide in an R-F transmission line. The noise generated due to the loss of R-F signal is given by:

$$(1-\frac{1}{L})T_o$$

This, however, only takes care of the absorption re-radiation effects. The fact that the signal is attenuated must also be injected. Thus the effective noise temperature of such a system is given by:

$$L(1-\frac{1}{L})T_o = (L-1)T_o$$

Thus if one has a loss of 2 db in the waveguide this represents re-radiation of 100°K or so and an effective noise temperature of 180° or so. By taking the attenuation factor into consideration one may easily convince himself that any attenuation in a waveguide run is serious, especially in low noise receiver systems.

Sincerely,
WILLIAM H. FROM

• ● •

We wish to emphasize again that the "journal" is interested in receiving papers from the industry.

Papers can be addressed to "the microwave journal," 159 Linden Street, Wellesley 81, Mass. In the West Coast area, please address all communications to "the microwave journal," Box 1134, Palo Alto, California.

We cordially invite your participation.

CONTRIBUTOR'S BIOGRAPHIES

ROMAYNE F. WHITMER

Romayne F. Whitmer received the degree of BS in EE in 1946 from the University of New Mexico and the degree of MS in EE from the University of Washington in 1948. He then joined the Research Laboratory of Sylvania Electric Products at Bayside, New York, where he worked in the fields of electron optics and traveling wave tubes until 1952. During this period he continued his studies at the Polytechnic Institute of Brooklyn and was awarded the degree of DEE in electron physics in 1956.

From 1952 to 1956 Dr. Whitmer was a staff member of the Los Alamos Scientific Laboratory, where he worked on problems concerned with the interaction of electromagnetic waves with plasmas. Since 1956 he has been employed by the Microwave Physics Laboratory of Sylvania Electric Products, Mountain View, California, where he is Head of Theoretical Studies. He is currently engaged in studying non-linear phenomena in plasmas.

Dr. Whitmer is a member of Sigma Xi, Sigma Tau, Kappa Mu Epsilon, the American Physical Society, and the IRE.

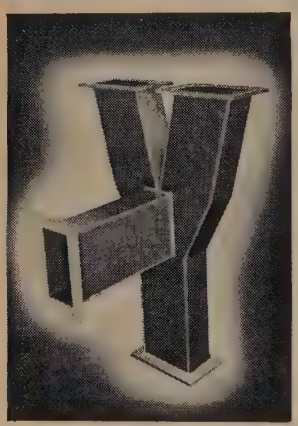
PAUL G. RAJCOK

Paul G. Rajcok received his B.S. degree from Lehigh University, Bethlehem, Pa., in February, 1948 after spending 4 years as an Army Air Force navigator during World War II. After graduation, he was employed by the Western Electric Co., Allentown, Pa. as a Product Engineer on miniature glass tubes with developmental responsibility for automatic glass sealing and exhaust machinery. His past eight years were with Sylvania Electric Products, Inc., Woburn, Mass. with various engineering responsibilities on gaseous discharge microwave tubes and ferrite devices. Currently he is employed in organizing the Top Manufacturing Company, Boston, Mass.

GERSHON J. WHEELER

Gershon J. Wheeler has been in the field of Microwaves since 1942. At present he is an Engineering Specialist at Sylvania's Microwave Physics Laboratory, in charge of ferrite device development and consulting on special microwave problems. Before this, he was a microwave consultant at Raytheon Manufacturing Company, where he was employed from 1950 to 1957. He is a senior member of the IRE and a member of RESA.
Mr. Wheeler is an Associate of "the microwave journal" and has been an instrumental force in its activities since inception.

I-T-E CAN SUPPLY ALL YOUR LARGE WAVEGUIDE TEST EQUIPMENT



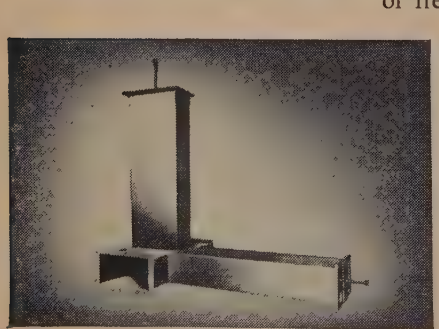
Folded hybrid tee

Slotted lines are supplied complete with probe and carriage. Residual SWR is less than 1.02:1 over the frequency band. Available in sizes WR770 through WR2300.

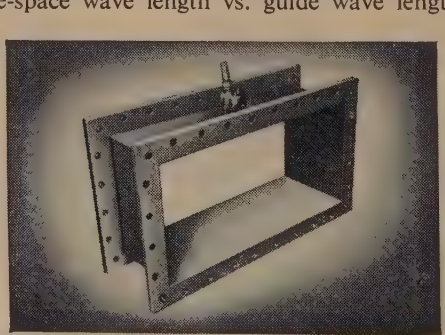
Here are a few examples of the waveguide test equipment and components currently available from I-T-E to meet the testing and operating requirements of multi-megawatt radar and scatter communications systems. This equipment reflects I-T-E's broad experience in all phases of large waveguide design and manufacture.

Take advantage of I-T-E's specialized knowledge of waveguide testing and the precision fabrication capabilities of a specially equipped waveguide shop. Facilities such as these assure you of the highest standards of quality, maximum economy, and excellent delivery—in single or production quantities.

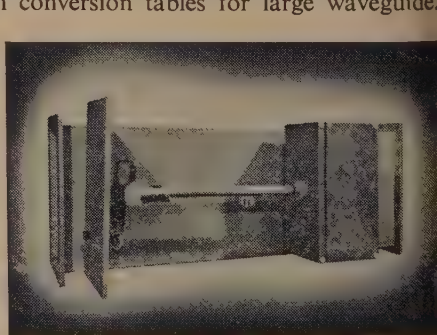
If you have a requirement or problem relating to waveguide test equipment, write I-T-E Special Products Division, 601 E. Erie Ave., Philadelphia 34, Pa. And ask for your copy of free-space wave length vs. guide wave length conversion tables for large waveguide.



E-H plane tuner



Close-loop directional coupler



Motorized short circuit section

I-T-E CIRCUIT BREAKER COMPANY
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PRINCIPLES OF MICROWAVE INTERACTIONS WITH IONIZED MEDIA . . . . . .

BY

R F. WHITMER SYLVANIA ELECTRIC PRODUCTS CO.
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PART 1

PLASMA RESONANCE

Introduction

The ionized gaseous medium is esently receiving as much attention microwave engineers as the ferro-gnetic medium received five years o. By using an ionized gas within waveguide it is now possible to ob-n an electronically controllable phase fter or switch, a crystal protector, or harmonic generator. Since a device ng an ionized gas does not neces-ily have the power limitations in-ent in a ferrite device, the compo-nt applications of the ionized me-im may exceed those of the ferro-gnetic medium. In addition, the vent of the space era has introduced ionized medium to the microwave gineer interested in communications l radar systems. For example, when upersonic vehicle enters the atmos-ere an ionized layer is produced in vicinity of this vehicle. Such an ized layer can be of major im-tance when considering communi-ion with this vehicle or its radar ectability.

The purpose of this paper is to dis-s the propagation characteristics of electromagnetic wave in the pres-e of an ionized medium. The con-ts needed to understand such prop-tion will be emphasized from the crowave engineer's standpoint. Part will discuss the concept of plasma onance and Part II, to be published the next issue, will discuss the effects electron cyclotron resonance on the pagation characteristics.

II. The Plasma

The term "plasma" was introduced by Langmuir [1] in 1929 and refers to an ionized gas which is electrically neutral. This implies that the effects of space charge forces are not important within distances comparable to the shortest length of interest. For the present discussion, this length is the wavelength of the electromagnetic wave under consideration. A plasma, therefore, must consist of an equal number of electrons and ions in order for it to be electrically neutral. In addition, a plasma may contain a number of un-ionized, or neutral, particles.

The theory to be derived in the following sections will be limited to the case of a weakly ionized plasma (less than 1% ionization). This allows the electron-electron and electron-ion collisions to be neglected in comparison with the electron-neutral particle collisions simply because of the relatively large number of neutral particles present in the plasma. In actual practice, most plasmas of interest to the microwave engineer are much less than 1% ionized. Furthermore, the ion current will be neglected in comparison with the electron currents. Since the mass of an ion is at least 1800 times the mass of an electron, the assumption that the ion velocity is negligible in comparison with the electron velocity is quite reasonable.

III. The Electromagnetic Wave

As a first approximation, let us assume that a uniform plasma completely fills all space and, furthermore, that no collisions of any type occur within the plasma. A wave propagating in this media must satisfy Maxwell's Equations

$$\nabla \times E = -\frac{\delta B}{\delta t} \tag{1}$$

$$\nabla \times H = \frac{\delta D}{\delta t} + J \tag{2}$$

where

$$D = \epsilon E \tag{3}$$

$$B = \mu H \tag{4}$$

$$J = env \tag{5}$$

and e is the charge of an electron, n is the electron density, and v is the velocity of an average (or typical) electron. MKS units will be used throughout this discussion. In addition, the equation of continuity must be satisfied,

$$\frac{\delta}{\delta t}(en) + \nabla \cdot J = o \tag{6}$$

where it is assumed that there is no source of electrons in the media. Furthermore, the electrons are acted upon by the electromagnetic field and their motion can be determined from the force equation

$$nm\frac{dv}{dt} = ne(E + v \times B) \tag{7}$$

Since it is known that

$$|H| = \sqrt{\epsilon/\mu}\,|E| \qquad (8)$$

the $v \times B$ term in Eq. (7) differs from the E term by the factor

$$\sqrt{\epsilon\mu}\,v = v/c << 1 \qquad (9)$$

and therefore the $v \times B$ term will be neglected. The latter statement is not necessarily true when a static magnetic field is present.

By multiplying Eq. (7) by e, and using Eq. (5), one obtains

$$-\frac{dJ}{dt} = \frac{ne^2}{m} E. \qquad (10)$$

Assuming that the field variables have the time dependence of $e^{-i\omega t}$ Eq. (10) yields

$$J = i\frac{ne^2}{m\omega} E \qquad (11)$$

and Eq. (2) becomes

$$\nabla \times H = \left(-i\omega\epsilon + i\frac{ne^2}{m\omega}\right)E. \qquad (12)$$

Recalling, for the moment, propagation in free space Eq. (2) would have been

$$\nabla \times H = -i\omega\epsilon E. \qquad (13)$$

Equation (12) can be put in the same form as the free space equation by introducing an effective dielectric constant ϵ'. Equation (12) then becomes

$$\triangle \times H = -i\omega\epsilon' E \qquad (14)$$

where

$$\epsilon' = \left(1 - \frac{ne^2}{m\epsilon\omega^2}\right)\epsilon. \qquad (15)$$

Therefore, the effects of the plasma on an electromagnetic wave can be represented by means of an effective dielectric constant.

From Eq. (15) it can be seen that the term $ne^2/m\epsilon$ has the dimensions of frequency squared. Thus, we may set

$$\omega_p^2 = \frac{ne^2}{m\epsilon} \qquad (16)$$

where ω_p is the plasma frequency. It has been shown, by Langmuir and Tonks,[2] that ω_p is the frequency at which the electrons oscillate about their rest positions. That is, if a group of electrons are displaced from their rest positions by an external force, a restoring force will be established due to the electric field between the electrons and the ions which have been left behind. In order for the plasma to remain neutral the electrons will tend to return to their original positions and will oscillate about their original positions due to inertial effects. The frequency of this oscillation is the plasma frequency. The effective dielectric constant can now be written as

$$\epsilon' = [1 - (\omega_p/\omega)^2]\epsilon \qquad (17)$$

and one can see that the effects of a plasma (in the absence of a magnetic field) are always to reduce the dielectric constant below that of free space.

If one now assumes that a plane wave will propagate in the medium with a dependence of $e^{\pm\delta z}$, a well known result of electromagnetic theory[3] is that

$$\delta^2 = -\mu\epsilon'\omega^2 \qquad (18)$$

or, using Eq. (17),

$$\delta^2 = -\frac{\omega^2}{c^2}[1 - (\omega_p/\omega)^2]. \qquad (19)$$

It can be seen that for $\omega > \omega_p$, the right-hand side of the equation is negative, and therefore δ will be imaginary. For this case let $\delta = i\beta$ and the wave will propagate as $\exp(-i\omega t \pm i\beta z)$. A plot of β as a function of ω_p/ω is given in Fig. 1. From this plot it can be seen that the phase velocity of the wave, that is ω/β, is always greater than the free space velocity and increases as ω_p/ω increases. For $\omega < \omega_p$ the right-hand side of Eq. (19) is positive and therefore δ is real. For this case, let $\delta = \alpha$ and the wave will be characterized by $\exp(\pm\alpha z)\ \exp(-i\omega t)$. The negative sign must be used due to elementary energy considerations. Thus it can be seen that for this case the wave does not propagate at all but is rapidly attenuated. At a boundary between free space and a plasma, for $\omega < \omega_p$, an incident wave would be totally reflected or attenuated similar to the phenomenon which occurs in a waveguide beyond cut-off.

Equation (16) can be written as

$$f_p = 8974\sqrt{n} \qquad (20)$$

or

$$n = 1.242 \times 10^{-8} f_p^2 \qquad (21)$$

where n is the number of electrons pe cubic centimeter. The preceding state ments may perhaps be clarified b an example. For an electron densit of 10^{12} cm^{-3} Eq. (20) implies tha frequencies above 8.974 kmc will prop agate through the plasma whereas fre quencies below will not. For a fre quency of 3333 mc Eq. (21) implie that an electron density above 1.24 $\times 10''$ will not allow propagatio whereas a density below this valu will.

Actually, the preceding picture of plasma is overly simplified since al collisions have been neglected. Col lisions, in general, are a mechanis by which the electrons can gain energ from the field. Equation (11) indi cates that, in the absence of collision the electrons will oscillate with the velocity 90° out of phase with th electric field. Therefore no power, o the average, can be taken from th field by the electrons. However, whe collisions occur, the electrons can los this phase relation and thereby gai energy. This, of course, must result i an attenuation of the electromagneti wave.

The effects of collisions can be ac counted for by adding a dampin term in Eq. (7). That is

$$nm\frac{dv}{dt} + nm\nu v = neE \qquad (22$$

where the $v \times B$ term has been ne glected. ν represents the electron neutral particle collision frequency an it should be noted that its effect is in troduced in the form of a viscou force. Equation (11) is now mod fied to read

$$J = \frac{ne^2}{m(\nu - i\omega)} E \qquad (23$$

and the effective dielectric constant b comes

$$\epsilon' = \epsilon\left[1 - \frac{\omega_p^2}{\nu^2 + \omega^2} + i\frac{\omega_p^2\,\nu/\omega}{\nu^2 + \omega^2}\right] \qquad (24$$

The fact that ϵ' is now complex i plies that the medium has some lo properties and it can be seen that th effects of this loss go to zero f $\nu = 0$. Also, the electron velocity not 90° out of phase with the elect field and therefore, the field can i part energy to the electrons.

Referring to Eqs. (18) and (19) will now be complex rather than ither real or imaginary. Setting

$$= \alpha + i\beta \quad (\alpha \text{ and } \beta \text{ are both real}) \tag{25}$$

here α is the attenuation coefficient nd β is the phase coefficient, α and β an be found from Eqs. (18) and 24). This can be accomplished easily it is assumed that

$$(\nu/\omega)^2 << [(\omega/\omega_p)^2 - 1]^2 \tag{26}$$

Inder this condition

$$= \frac{\omega}{2c}\left(\frac{(\omega_p/\omega)^2\,\nu/\omega}{[1-(\omega_p/\omega)^2]^{\frac{1}{2}}}\right) \tag{27}$$

nd

$$\beta = \frac{\omega}{c}[1-(\omega_p/\omega)^2]^{\frac{1}{2}} \tag{28}$$

The assumption made in Eq. (26) valid for most microwave applicaons. In many cases ν is approxiately proportional to the gas pres-re; for example, in hydrogen $\nu \approx \times 10^9$ p where p is the pressure in illimeters of mercury. Therefore, for is assumption to be valid at 10 kmc e pressure of hydrogen would have be less than approximately 1 millieter, for values of ω_p/ω up to apoximately 0.9. These values are well ithin the range of operation of most evices. When this approximation oes not hold the exact equations can derived but they are slightly more mplex to analyze.

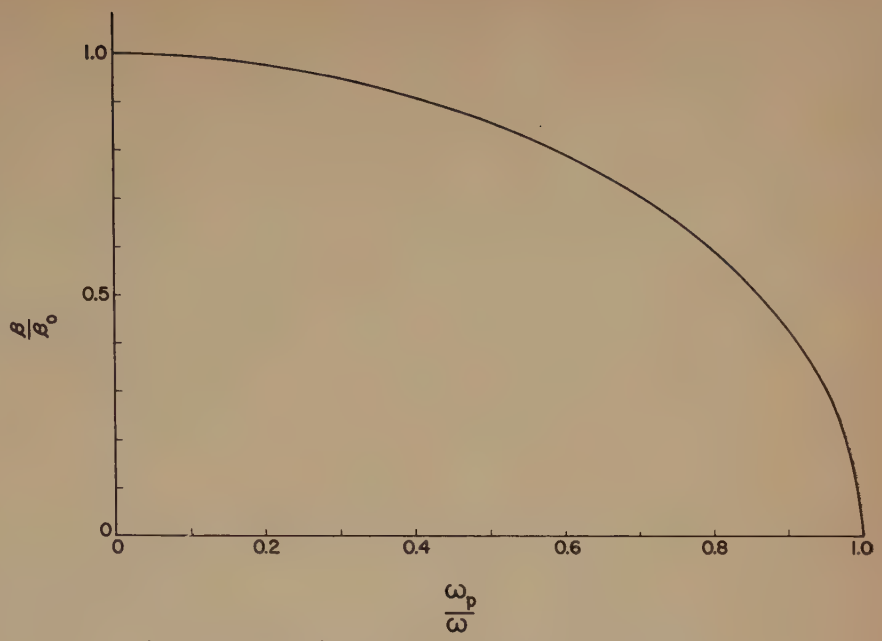

Figure I—1 — Phase coefficient versus electron density.

A comparison of Eq. (28) with Eq. (19) indicates that the earlier statements regarding propagation still are valid. For $\omega > \omega_p$ a wave will propagate, and for $\omega < \omega_p$ it will not. The introduction of the collison term has not changed this property of the propagation constant. However, referring to Eq. (27), the wave is now attenuated by an amount depending upon ν and ω_p. A plot of α as a function of ω_p with ν as a parameter is given in Fig. 2. This figure indicates that α increases as ν or ω_p increases and that α approaches an extremely high value as ω_p/ω approaches one.

IV. Conclusions

This elementary theory serves to illustrate the importance of plasma resonance on electromagnetic wave propagation. Frequencies below the plasma frequency do not propagate through a plasma whereas frequencies above the plasma frequency do. This result has obvious implications both from the communication and the device viewpoint. The theory also illustrates the importance of microwave techniques, to the study of plasmas. For example, by measuring the phase shift of a wave through a plasma one may obtain the electron density in the plasma and by measuring the attenuation one may obtain the electron-neutral particle collision frequency.[4]

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Part II of this paper, appearing in the next issue, will discuss the effects of a dc magnetic field on propagation through a plasma.

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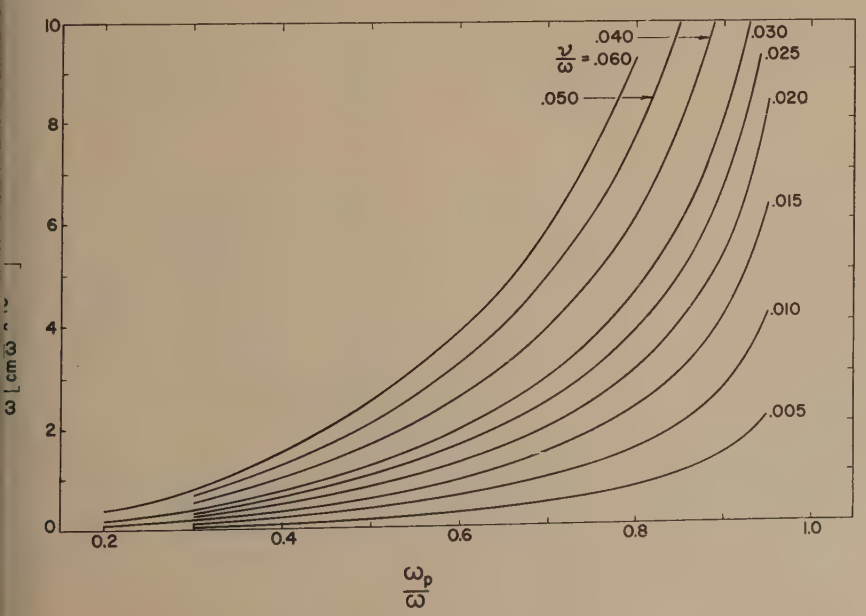

gure I—2 — Attenuation versus electron density for various values of ν/ω.

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THE development of the differential phase shift circulator by R. H. Fox of Lincoln Laboratories has led to a high powered compact circulator which has had widespread adoption in a number of new radar designs for basic duplexing. The advantages of this type of duplexer (in conjunction with a crystal protecting TR tube) are inherent magnetron-to-load isolation, improved high powered insertion loss (over a combination of tube type duplexing plus isolators) and reduction of power level to TR tubes, making possible higher powered operation of existing TR tubes, and improved recovery time characteristics with some minor improvement in tube life.

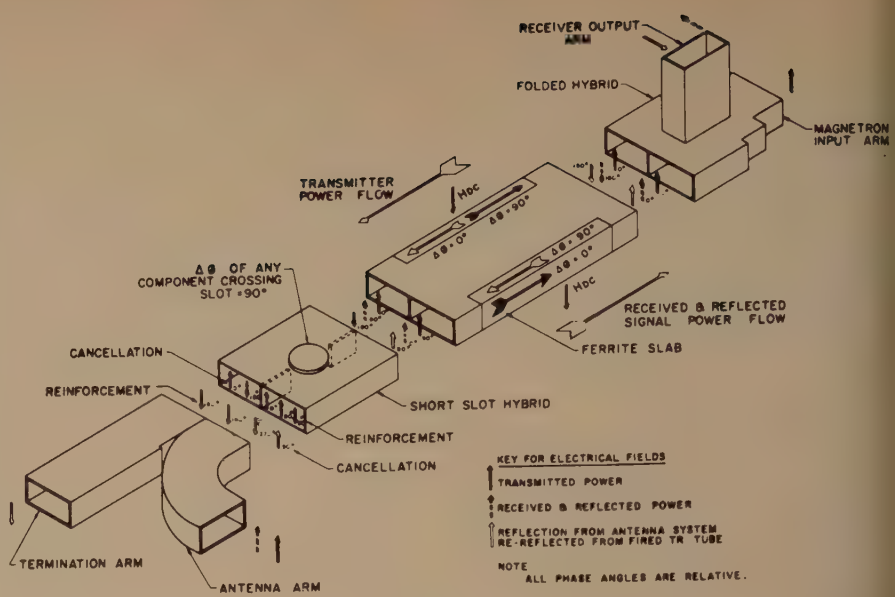


Figure 1

SYSTEMS APPLICATIONS OF FERRITE CIRCULATORS

TORE N. ANDERSON, AIRTRON, INC., MORRIS PLAINS, N.J.

The operating principle of the Fox type circulator will be reviewed here briefly. Figure 1 shows schematically the action of this type circulator.

Operation of Ferrite Phase Differential Duplexer

A folded hybrid is used at the input section, connected to two different phase shift sections, which are loaded with ferrite and biased in such a way as to provide a differential phase shift of 90° for either direction of transmission thru the ferrite loaded waveguides. A short slot hybrid then completes the unit to provide circulating action.

As contrasted to the Faraday rotational types of circulators, the bandwidth limiting feature of these units is the hybrids themselves. With most ferrites in the X to Ka-band regions, operated below saturation, the change of phase shift per unit length is almost exactly compensated by the change in the number of guide wavelengths thru the phase shift sections so that over 12% bands, the relative phase shifts encountered with most normal ferrites, even those using dielectric loading, is less than about 3°. Thus, with this arrangement, it is possible to obtain isolations in excess of 25 db over the entire 12% operating frequency range capabilities of the hybrids. Since the ferrite themselves are bonded to the waveguide walls, which are excellent heat sinks, extremely high powered operation of these units has been obtained.

Table I summarizes the results obtained to date with Fox[1] type circulators.

In designing a Fox type circulator for use in a high powered radar set, it is imperative that the ferrite meet certain requirements. The first of these is high Curie temperature and, second, a saturation magnetization suitable for the frequency range involved. The lower the frequency in general, the lower the saturation magnetization required to reduce domain wall losses. The higher power applications will also dictate extremely high Curie temperatures because of the relatively poor thermal conductivity of the ferrite materials. A class of materials that meet these requirements have been a family of ferrites which are basically nickel-aluminates. These materials exhibit Curie temperatures in excess of 500°F for a wide range of aluminum additions. It is important, of course, in any of these, to provide the narrowest possible resonance line width so as to provide a region between the zero field domain wall losses and the losses due to gyromagnetic resonance which is sufficiently low loss to be practical for high powered duplexers. For the majority of these applications, nickel-aluminates with

1. Kales, Chait and Sakiotis of NRL, about the time of the original work by Fox, showed similar constructions.

minor additions of cobalt and copper have been used with good success. Saturation moments range from 1800 in the C-band units to 3000 in the 35 Kmc units. Examples of these are shown in Figures 2 thru 6.

One of the serious problems in applying ferrites to high powered circulator applications in the lower frequency regions is the non-linear behavior with power level which results from the excitation of spin-waves which couple energy from the uniform precession of the magnetization (as first worked out theoret-

High Power Circulators Used for Radar Duplexing

TABLE 1

Frequency Mc/s	Power Handling Avg. watts	Peak, Kw	Insertion Loss Db	Isolation Db	Remarks
5400-5700	1800	——	0.4	30	CW application
7500-8500	1800	——	0.3	30	CW application
8500-9600	400	500*	0.3	30	X_1
8500-9600	1250	2000*	0.3	30	X_1 tests made in progressive resonator
16,000-17,000	140	140	0.4	30	Pulse radar
34.5-35.5	50	100**	0.2	30	Pulse radar

*Pressurized to two atmospheres

**Pressurized to four atmospheres

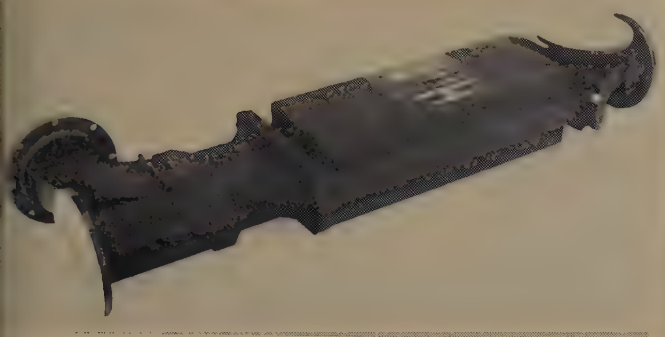


Figure 2—CW High powered circulator for C-band, 1800 watts.

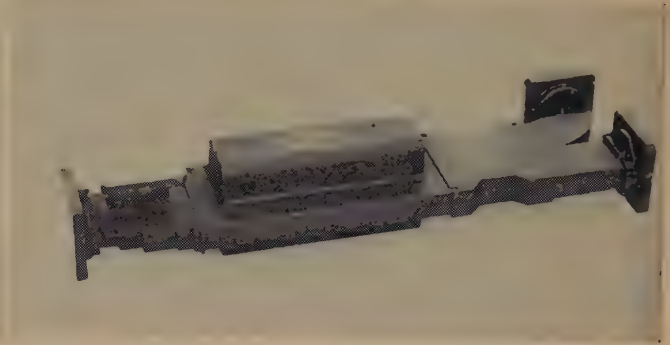


Figure 3—CW high powered circulator for X-band, 1800 watts.

Figure 4a — X_1 high powered pulse circulator for 8.5 to 9.6 KMc., 500 Kw.

Figure 4b — X_s high powered circulator for 8.5 to 9.6 KMc., 250 Kw.

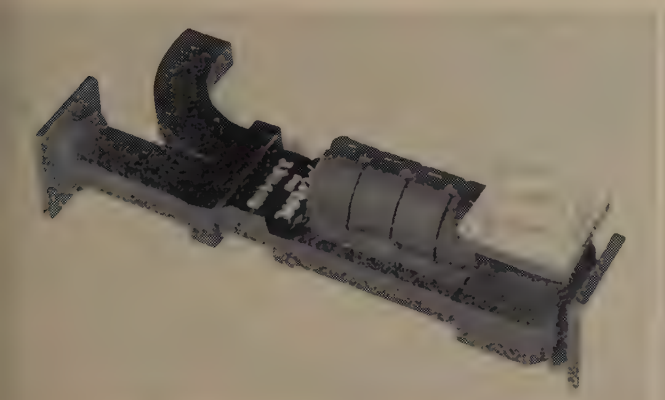


Figure 5 — K_u high powered circulator for 16.5 to 17.5 KMc., 150 Kw.

Figure 6 — K_a high powered circulator for 34.5 to 35.5 KMc., 100 Kw.

ically by Suhl and Walker of Bell Telephone Laboratories). The threshold power level for the onset of non-linear absorption is determined mainly by the geometry and the linewidth of the ferrite used. Suhl has shown that the appearance of the subsidiary absorption peak is due to the excitation of non-Z directed spin-waves (Z being the direction of the applied field). These spin-waves grow exponentially at the expense of the uniform precession when the rf field exceeds certain threshold values. Unfortunately, this subsidiary absorption peak occurs at biasing fields that are normally used in the lower frequency applications between the main gyromagnetic resonance and the domain wall loss mechanism and thus it is difficult with normal ferrites to find an operating region for high power which is free of loss mechanisms. Therefore, for high peak power circulator designs, it is necessary to operate in the lower frequency regions above gyromagnetic resonance and satisfactory results have been reported down to S-band using this technique.

For CW applications, however, it has been possible to build circulators capable of handling considerable power levels with biasing fields below resonance and examples of these are shown below.

Improved Recovery Time Characteristics

In the basic circulator arrangement, the transmitter is connected directly to the antenna with the antenna reflections being the primary source of energy impinging on the TR tube. The isolation achievable in practical applications of ferrite circulators is limited by this antenna reflection and may be as low as 10 db for antenna mismatches in the order of 2 to 1. Therefore, it is thus necessary in practical systems to incorporate a crystal protector TR tube. Gas fills which are particularly good in recovery time characteristics can also be used to advantage in such systems because the power levels are 10 db lower than otherwise.

The effect of improved recovery time characteristics can be readily demonstrated. Taking a ferrite circulator with a crystal video receiver and synchronizing a transmitting magnetron to provide 1 microsecond pulse and using a simulated receiver

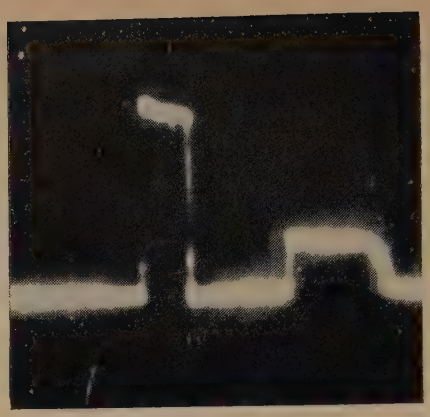


Figure 7a—Ferrite circulator with crystal video receiver, to eliminate IF ringing effects. Transmitted pulse 1 μsec — received pulse 2 μsec.

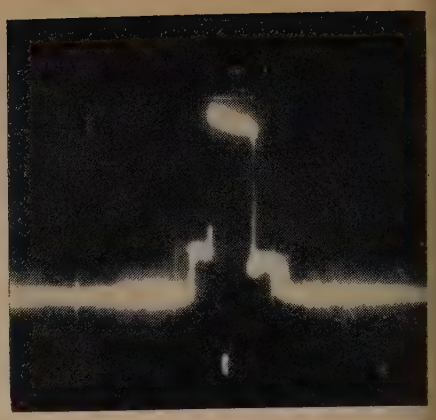


Figure 7b — Same as Fig. 7a except superimposed.

(low powered magnetron) to return a receive signal to the circulator, 3 microseconds wide, the improved recovery characteristics of the ferrite circulator can be vividly demonstrated. Figure 7, a and b, shows the improved recovery time characteristics. Figure 7a shows the shape of the pulses spaced to approximately one microsecond. Figure 7b shows the same pulses superimposed and as can be seen, there is practically no pulse shape degradation with the ferrite circulator and TR tube combination under matched load conditions.

Specialized Circulator Designs

As in any application of microwave components, there are always specialized versions to fit applications where one or two parameters, size, weight or performance, are governing criteria.

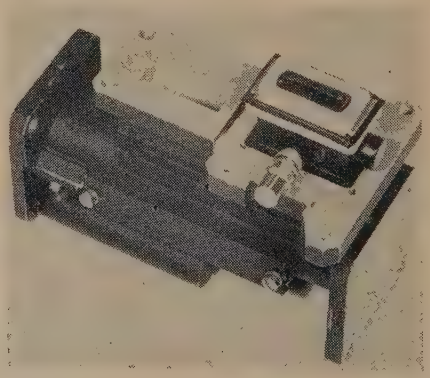
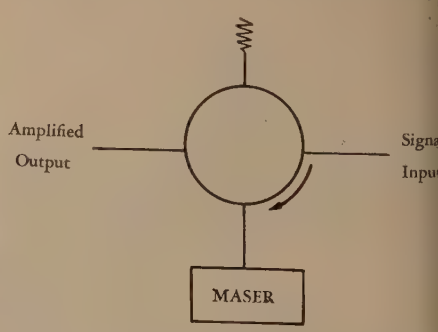


Figure 8 — Commercial airlines weather radar duplexer for minimum size and weight, 9.375 KMc, 40 Kw, Faraday rotation.

Figure 8 shows a ferrite duplexer designed for commercial airborne weather radar application where size and weight were paramount. Here, because of the medium power classification, 40 kw at altitudes up to 30,000 feet, a Faraday rotator type duplexer was used with unique orthogonal coax-to-waveguide junctions to provide the basic four-port circulator. The TR tube is a 3 element TR with contact type flanges for mating against the mixer; the AFC port is a Bethe hole in the Faraday rotation region to provide a small AFC sample. A fourth arm is terminated in a coaxial load to absorb antenna reflections (which are re-reflected from the TR tube during high level operation.) This unit has successfully met an insertion loss specification of .4 db with better than 25 db isolation over the narrow operating range at 40 kw peak power, 40 watts average, and 30,000 feet altitude.

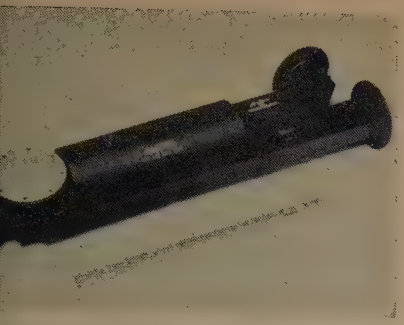
Circulators for MASER Operation

A number of the new MASER amplifiers have but a single port. It is necessary, therefore, in order for signals to enter and amplified signals to leave the MASER cavity, to provide a circulator which is connected schematically as shown below.



Circulator used with single port "Maser."

For this application, it is possible, because of the low power involved, to use materials with Curie temperatures that are extremely low. With such materials, magnesium manga-



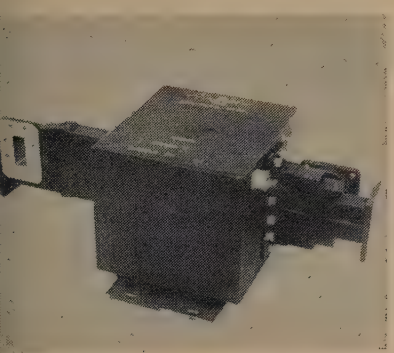
ure 9 — Low insertion loss circulator for maser applications.

se aluminates in general, circula- s have been built with insertion ses as low as .1 db in the lower equency bands, 1000, 3000 and 00 mcs. Figure 9 shows a C-band culator with only .1 db insertion loss this application.

tenna Switching Means of Circulators

Figure 10 shows a switched cir- ator which provides in a single it a switching mechanism from e transmitter to either of two an- nas with the novel arrangement at all receive signals automatically e reflected into the receiver arm.

This is basically the Fox circulator anged with an electromagnetic ld coil which provides the dc bias- g field in one direction for one out- t arm and must be reversed to itch to the opposite output arm.



ure 10 — Switched circulator-duplexer Xs, 8.5 to 9.6 KMc, 250 Kw.

As a result of the non-reciprocal arrangement, all returning signals, regardless of which arm is connected, automatically return to the receiver arm. Likewise, any antenna mismatch is reflected from the TR tube and re-radiated out the other antenna arm.

For this unit, two coils in parallel are used operating from 150 volts dc and requiring 115 milliamperes each. Coil resistance is 1300 ohms. Switching time for this unit is approximately 3 milliseconds and a dual triode such as the 6080 can readily handle the switching for electronically controlling antenna selection. Insertion loss and isolation are identical to the fixed field circulators.

Combining Transmitters and Receivers with Circulators

Another unique application of circulators is the combination of transmitters or magnetrons on a single antenna without appreciable loss. Heretofore, directive couplers were required for this purpose with inherent coupling losses. Figure 11 shows the scheme for doing this.

Transmitter No. 1 covers a specific frequency band. Transmitter No. 2 covers another frequency band. By the very nature of magnetrons, Transmitter No. 1 will present over the frequency range No. 2, essentially, a lossless short circuit. Signals from Transmitter No. 2 then enter the circulator, go into Transmitter No. 1 arm where they are reflected by this short circuit, re-enter the circulator, and go directly to the antenna. Receive signals of both frequencies go into the receiver arm directly by circulator action.

Conclusions

The use of the Fox type ferrite circulators for radar duplexing applications have a number of inherent advantages. The transmitter losses are lower than a comparable tube duplexer and isolator combination. The recovery time is substantially improved. The possibility of switching and combining transmitters offers outstanding features and the inherent transmitter to load isolation in this type of duplexing scheme offers attractive advantages. With circulators of this type it should be possible to extend the high power performance of existing TR tube designs without additional tube development and this has already occurred in several frequency ranges.

Like all microwave component development, there are pros and cons to be considered in each application.

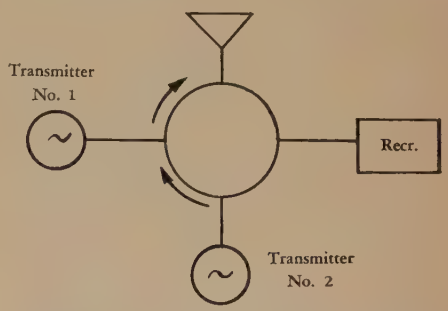


Figure 11 — Method of combining transmitters with circulators to a common antenna.

Ferrite circulators used as duplexers do introduce additional receiver loss as compared to tube type duplexers so one must weigh the improved transmitter performance against the slight decrease in receiver performance coupled with the other features for the individual application. The possibilities of switching and combining transmitters which were described, however, introduce compensating features to make the use of such ferrite circulators attractive. With the advent of improved ferrites and other material such as the garnets, the extension of these principles to the lower frequency regions should be possible.

USING THE SMITH DIAGRAM . . . II

by
GEORGE C.
SOUTHWORTH

THIS IS THE fourth in a series of articles about Phillip H. Smith and the diagram which bears his name. The first two articles were general in nature and led naturally to questions about the structure of the Smith diagram and the kinds of problems that may be solved by its use. First steps toward answering these questions were taken in the previous article. It was entitled: *Using The Smith Diagram — Part I.* The present article continues answering these questions and naturally forms Part II of this series.

In Part I, it was explained that the Smith diagram consists of a series of superimposed grids such that as certain significant transmission-line data are plotted on one grid, other significant data may be read from other grids. These graphical interrelationships are of very great practical importance for they permit, without extended calculations the solutions of most practical problems encountered in transmission-line practice.

In the previous article, the construction of the various grids was explained. Especially significant is the grid on which are plotted impedance relationships, as for example the impedance in which a transmission line may be terminated. This grid provides not only for resistance components but for both positive and negative reactive components. In all three cases all values from zero to infinity may be accommodated. Together these grids are of such a nature that useful data emerge in a most remarkable manner. For example, knowing the values of the impedance components, and plotting the same on the diagram, one may scale from another superimposed diagram the voltage standing wave ratio. Though not mentioned, one may also scale from still another grid the reflection coefficient. Conversely one may plot either standing wave ratio or reflection coefficient and obtain values of terminal impedance. Also of importance is the fact that this chart gives data concerning the appearance of the terminal impedance when viewed from other points along the line. In this connection it was shown that the line acted as a transformer

Figure 1 — Diagram from which the input admittance of a dissipationless line may be scaled for each of several output admittances specified by points A_1, A_2, A_3 and A_4.

providing a wide range of impedances including pure resistances both larger and smaller than characteristic impedance.

Various numerical examples were cited to illustrate the range of impedances available. Most problems assumed that the line was free from loss but one special case assumed that the line had considerable loss. In this case the locus of available impedances spiralled to the center of the diagram. Numerical problems cited in the earlier article assumed in all cases, im-

dances expressed by $\overline{Z} = \overline{R} + i\overline{X}$. e present article will depart from t procedure and assume admittances pressed by $\overline{Y} = \overline{G} + i\overline{B}$. This is ne with a view to encouraging equal niliarity with both quantities by the dent reader. The present article will o feature devices fabricated from veguide components. Often the mponents are irises or perhaps in-ctive posts, appropriately spaced in ection of guide.

ore Numerical Problems

It is an extremely useful feature of e Smith diagram that it may be used erchangeably for plotting either im-dances or admittances. Also either antity, when so plotted, may be con-rted to the other merely by shifting e locus to a diametrically opposite int on the diagram. Examples fol-v:

Referring to Fig. 1, it is readily seen at point A_3 corresponding to $\overline{Y} = + i\infty$ when carried to the opposite int on the diagram becomes: $\overline{Z} = + i0$. Likewise for point A_2 hich corresponds to $\overline{Y} = 1 - i1.4$ en transferred to the opposite point the diagram becomes: $\overline{Z} = 0.34$ i0.47. This may be verified by the lowing steps:

$$\overline{Z} = \frac{1}{\overline{Y}} \text{ or } \overline{R} + iX = \frac{1}{\overline{G} + i\overline{B}}$$

$$\text{or } \overline{Z} = \frac{\overline{G} - i\overline{B}}{\overline{G}^2 + \overline{B}^2}$$

numerical substitution we find that

$$\overline{R} = \frac{1}{1 + 1.96} = 0.338 \text{ and}$$

$$\overline{X} = \frac{1.4}{1 + 1.96} = 0.473$$

As a second numerical example to solved by Fig. 1, assume that a pure ceptance of $\overline{B} = + i0.7$, perhaps the form of a capacitive iris, is con-cted across a section of waveguide eady terminated in its characteristic mittance. The susceptance B, to-her with the normalized conduc-ce of unity, representing the char-eristic admittance of the guide, cor-ponds to a normalized admittance $\overline{Y} = 1 + i0.7$ and, therefore, to int A_1 on Fig. 1. It is convenient regard the introduction of this sus-tance as having shifted the operat-g point on the diagram from point corresponding to zero standing wave io, along a circle of unit conduc-tance to point A_1. This point lies on a circle of constant standing wave ratio, which we find, by means of the scale at the top of the figure, to be 6 db. This agrees with results calculated by means of Equation 9 of the previous article.

Facts relating to standing wave ratio alone are very useful, but, as already explained, the admittance diagram may provide much additional information. For example, the circle $A_1B_1C_1D_1$ is the locus of all possible values that the normalized susceptance $\overline{B} = + i0.7$ may assume when viewed at more remote points along the axis of a lossless guide, as we move toward the generator. The accepted convention in this case is such that distance measured toward the generator corresponds to a clockwise motion around the circle of constant standing wave ratio. It will be noted that at point B_1 the load appears as a pure conductance, greater than characteristic admittance; at C_1 it appears as a load of $\overline{Y} = 1 - i0.7$; and at D_1 it appears again as a pure conductance, but, this time, it is less than characteristic admittance. It will be seen, too, that at intermediate points between $A_1B_1C_1$, etc., the apparent load is complex and may assume a large variety of values as specified by the chart. It is this wide range of possible admittances presented by a straight piece of waveguide and its associated load that makes it such a valuable waveguide element.

It is of interest, in passing, to note that B_1 on the diagram corresponds to a point of minimum voltage in the standing wave. D_1 is the corresponding point of maximum voltage. It is a quarter wave nearer the generator. Both are convenient datum points as we have already seen.

Referring again to Fig. 1, it will be noted that at a point C_1 the input admittance is $\overline{Y} = 1 - i0.7$. It is evident that, if we introduce at this point, in the guide, a susceptance $\overline{B} = + i0.7$, the operating point will return along the circle of constant conductance C_1o to the origin. This corresponds to a condition of no standing wave ratio and hence to a condition of match. The discontinuity necessary for bringing this about is identical with that originally introduced. Reference to the scale on the outermost circle of the chart shows that the separation between admittances will be, for this case, approximately 0.198λ.

In the practical case, one of the two susceptances just referred to may be due as before to a discontinuity inadvertently introduced into the guide by a bend, or perhaps to an imperfection in construction, while the second may be a corrective measure to restore electrical smoothness. It is possible, too, that both susceptances may have been introduced quite deliberately to form, between the two, a resonant cavity having some particularly desirable frequency characteristic. In either case, the combination of the two discontinuities can be made essentially nonreflecting. These and other practical applications will be considered later.

As the third numerical problem, let it be assumed that the discontinuity introduced into the match-terminated guide had been in the nature of a negative susceptance of magnitude $\overline{B} = -i1.4$, perhaps due to an inductive iris, then the operating point would have been shifted from the origin to point A_2, corresponding to $\overline{Y} = 1 - i1.4$, and the range of admittances would have been that specified by the circle A_2, B_2, C_2, D_2. On the other hand, if the admittance had been in the form of a pure conductance $\overline{G} = 5.0$, the operating point would have shifted to A_3, and the range of possible admittances would have been specified by A_3, B_3, C_3, D_3. In an extreme case, a nearly perfect conductor may be connected across the guide, and then the locus of possible admittances will be specified by a circle passing around the periphery of the diagram. This corresponds to a circle of nearly infinite standing wave ratio A_4, B_4, C_4, D_4. It will be observed, in this case, that points B_4 and D_4, which lie on a circle of unit conductance, are also closely adjacent to A_4. These points correspond respectively to a very large negative susceptance, a very large positive susceptance, and a very large conductance, presented by the conducting septum. C_4 on the diagram, which represents a point in the waveguide a quarter wave removed from the conducting plate, corresponds to an admittance made up of an extremely small conductance. This point is of considerable practical importance, for it simulates the conditions assumed to exist at the end of an ideal open-end transmission line.

The Closed End of a Waveguide

One of the simplest and perhaps most useful waveguide elements is a

short piece of waveguide closed at one end by a transverse metal plate. In most practical cases, the plate assumes the form of a sliding piston. Experiments show that if the piston is well designed the coefficient of reflection is only slightly less than unity, indicating that the corresponding losses are very small. Such a device may therefore be used to approximate at a specific point in a waveguide the admittances specified by the outermost circle of Fig. 1. It will be remembered that at one point on the circle the admittance is an extremely large transverse conductance, while at another point it appears as an extremely small conductance. At other points the resultant admittance is a nearly pure susceptance which may be made to vary from extremely large positive values through zero to extremely large negative values. It is the limiting values of nearly infinite susceptance, both positive and negative, as well as the wide range of values between, that make this simple circuit element so very useful.

In one simple application of the foregoing principle a section of waveguide, an integral number of half waves long, is used to translate the nearly infinite admittance of the piston to other points further along the guide. In the practical case, these latter points may not be accessible for the actual introduction of an infinite admittance. Another practical use is based on the fundamental properties of a quarter-wave line which inverts the characteristics of the load connected to its terminals. In this instance, it becomes possible for the nearly perfect piston to appear at a point a quarter wave further along the line, as a nearly infinite transverse resistance (zero conductance). These quasi-insulators may be used in a variety of ways. One specific application of the quarter-wave stub is in connection with waveguide terminations.

It may be remembered that in our ordinary low-frequency practice it may be possible to match-terminate a transmission line, merely by connecting across its open end a resistance equal numerically to the characteristic impedance of the line. In waveguides, certain complications arise that make this simple procedure impracticable. For instance, radiation issuing from the open end has the effect of connecting across the guide an added conductance that is altogether inappropriate for match. Then, too, in most practical cases losses by radiation are undesirable and should be avoided. We may obviate these various difficulties by attaching to the end of the waveguide the conducting plate and its associated quarter-wave line, thereby eliminating radiation and, at the same time, providing the nearly zero transverse conductance and susceptance ordinarily associated with the ideal open-end transmission line. If, to this combination, we now connect at the quarter-wave point, the correct transverse conductance (characteristic admittance M), perhaps in the form of a crystal detector, we shall have met, ideally at least, the requirements for critical termination by a device that enables us to make efficient use of substantially all of the received wave-power.

In addition to the particular applications just mentioned, the piston and waveguide combination may be attached as a branch or a stub to a main waveguide, to provide, within a variety of susceptances. Though such stubs are very useful devices and their analysis represent interesting applications of the Smith diagram, they are regarded outside the scope of the present article.[1]

A somewhat elaborated form of the waveguide element just described consists not only of the piston and section of waveguide but of a transverse susceptance as well. The susceptance may, for example, be an iris of the kind shown in Fig. 1 of the earlier article. The result is in effect a kind of resonant chamber such as shown in longitudinal section in the last of the five illustrations in Fig. 2. As we shall later see, resonance is but one of its many possible conditions of operation.

Most of the characteristics of the chamber may be understood very readily from an admittance-diagram analysis. This will be made in connection with Fig. 2. Points a, b, c, etc.,

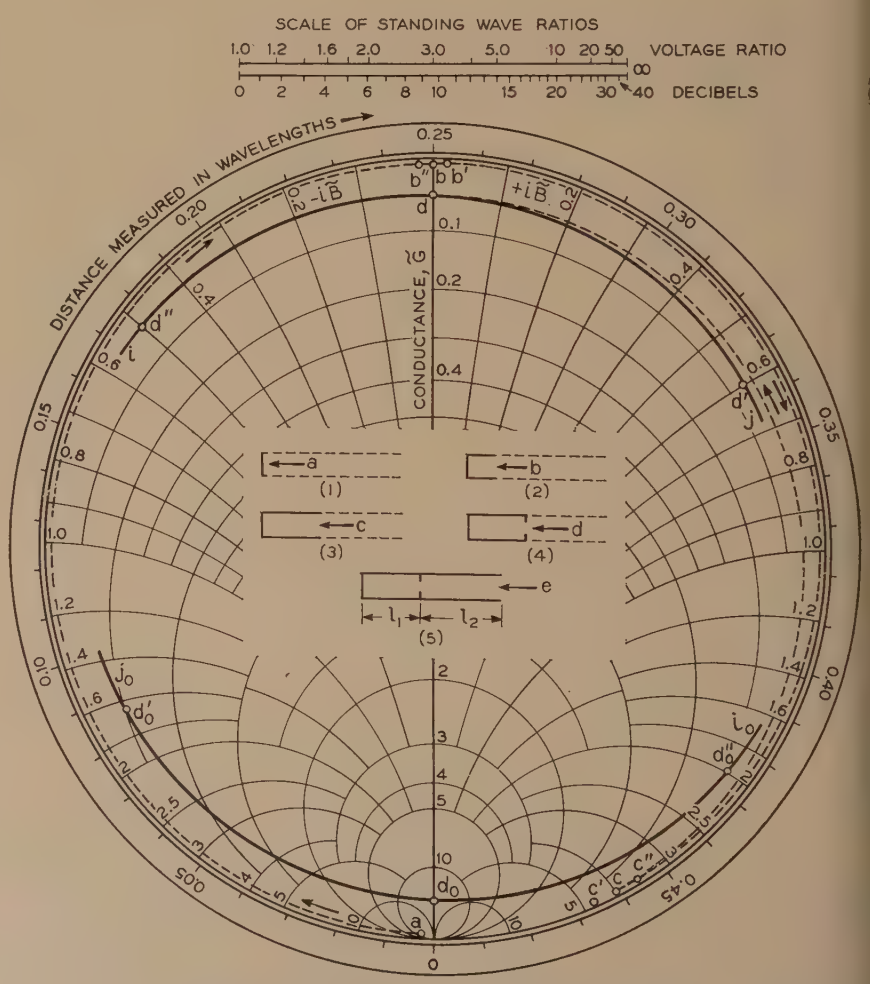


Figure 2 — Loci of admittances presented by a closed-end section of waveguide for various conditions represented by figures 1 to 5.

[1] For further discussion of stub tuners, the reader is referred to Principles and Applications of Waveguide Transmission—G. C. Southworth, D. Van Nostrand and Co. 1950.

vn in the longitudinal sections of chamber, correspond to similarly gnated points on the diagram.

rom a point near the end wall of chamber, shown at (1) of Fig. 2, admittance looking toward the is very large. This may be repre-ed by point a near the bottom of diagram. When viewed from more ote points along the guide, this ap-nt admittance takes on values spe-d by points on the dotted circle extending around the periphery ne diagram.

will be noted in passing that if waveguide line had ended at the ter-wave point (2) correspond-to point b at the top of the dia-n, the admittance looking into the e would have been a very small conductance. This is one of the litions of operation previously dis-ed in connection with the wave-le stub. However, for present pur-s we will assume that the line is nded as in (3) to a point c cor-onding to a length only slightly than a half wavelength ($l/\lambda = 1$), where the admittance, for the icular example chosen is, $\overline{Y} = + i4$. If, at this point, we place ss the guide a susceptance $\overline{B} =$ í, perhaps in the form of an in-ive iris to form a chamber as il-ated in (4), the resultant sus-ance will be zero, and the operat-point on the diagram will be car-along a circle of constant conduc-e $\overline{G} = 0.05$ to point d near the of the figure, where the resultant ittance is now a small conduct-. It will be obvious that, by choos-other lengths of chamber and r susceptances, point b might have located at any other desired point he diagram. Thus a chamber of kind here described may provide, proper proportioning, a large va-of admittances. Because the case re the admittance is a small pure luctance is very important, we will inue with that as a special ex-le.

will be noted that points b and the diagram are in close proxim-This suggests that substantially the results may be obtained from a ter-wave line (or odd multiples thereof) as from the particular chamber here assumed. There is, however, a very important difference. To illustrate how these two devices may differ, let it be assumed that the frequency is varied through narrow limits, resulting thereby in a change in the electrical length of the chamber so that point b moves to b′ (or b″) and point c moves to c′ (or c″). For the arbitrary frequency shift here assumed, the limits c′ c″ correspond to a much larger increment of normalized susceptance than do the limits b′ b″. Furthermore, since the susceptance of the iris itself remains sensibly constant with frequency, a shift of point c between limits of c′ c″ has the effect of shifting d between limits of d′ d″. Though the increment of susceptance change between d′ and d″ is the same as between c′ and c″, the percentage change is now very much larger. Comparing the distance between d′ and d″ with that between b′ and b″ we see that for the chamber, the change in susceptance with frequency is very much greater than for the case of the quarter-wave line. Accordingly, the chamber should be very much sharper in its frequency response accordingly, the chamber should be much sharper in its frequency response. Referring again to Fig. 2 it will be seen that the scale of susceptances is non-linear with respect to frequency (angular distance around the diagram).[2] As a result the susceptance increments between d and d′ and between d and d″ are unequal. For this reason the frequency-response characteristic of the chamber will be correspondingly asymmetrical.

Thus far the characteristics of the chamber have been viewed from a point immediately outside the iris, a condition represented by (4) in Fig. 2. The characteristics to be found at that point are summarized by the locus of impedances ij shown on the diagram. It is of interest to know also how the admittance characteristics of the chamber vary when viewed from more remote points such as that located at a distance l_2 in the last of the series of longitudinal sections shown in Fig. 2.

From principles of the Smith diagram as already set forth, the result of viewing the chamber from increasing distances along the line has the effect of rotating every point in the locus ij about the center of the figure. If the distance l_2 were increased by an integral number of half wavelengths, the locus would of course return to its present position, but, if it were made an odd number of quarter waves, the locus would assume a diametrically opposite position as represented by the arc $i_o j_o$. Since this falls in a region of very high admittances (very low transverse impedances), small changes in frequency will again result in large changes in admittance, but this time the changes are either side of the conductance axis varying from very large admittances at d_o to relatively low admittances at d_o' and d_o''. This quarter-wave location is another favored condition of operation.

Like the piston and waveguide combination discussed in the earlier part of this section, the chamber may be attached to a main guide as a stub or branch to produce, within, a variety of susceptances. For one of the conditions of operation just described, the chamber and branch may function as a band-pass filter while for the other it may serve as a band-elimination filter.

Matching with Lumped Reactors

When a discontinuity is placed across a waveguide, a portion of the incident wavepower is absorbed, a portion is transmitted into the medium beyond, and a portion is reflected. Because of reflection, a standing wave will be set up on the incident side of the discontinuity. It is of interest that certain observable characterisitcs of the standing wave provide important information about the nature of the discontinuity as well as the necessary steps for eliminating the standing wave. These characteristics will be discussed in the paragraphs that follow.

It is characteristic of standing waves that, at points of maximum voltage, the admittance seen when looking toward the load will appear, regardless of the exact nature of the load itself, as a pure conductance having a magnitude less than the characteristic ad-

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illustrative example chosen for Figure 2 may not be altogether representative of practical experience. The particular ues assumed were chosen partly with a view to avoiding a nfusion of circles near the outer reaches of the circle. It may a profitable exercise for the reader to speculate on the results, suming that the end wall of the chamber had presented a much larger initial conductance, thereby throwing the circle a b c nearer to the boundry of the diagram. Also he may wish to inquire into the effects of increasing the length of the chamber, thereby making point c fall in the region of very high admittances.

mittance of the line. At points of minimum voltage, the admittance will again appear as a pure conductance, but this time it will be greater than chraacteristic admittance. This implies that at some point along the line intermediate between these two limits, the load may present a conductance component that is just equal to the characteristic conductance of the line. This is true, as may be shown by the analysis, but there will be present along with the required conductance a substantial susceptance component, and hence match cannot be obtained by this simple expedient alone. To complete the match we must introduce, at the latter point, a second susceptance of the proper magnitude and sign. This method is usually referred to as matching with lumped reactors. As will be noted, two requisites must be met. First, a distance 1 along the line must be chosen such that the load is transformed into an admittance having a conductance equal to the characteristic admittance of the line. Second, a compensating susceptance, B′ of proper magnitude and sign must be introduced so that the resulting susceptance is zero. A possible discontinuity and also an arrangement suitable for its compensation are shown schematically in Fig. 3 (a). An equivalent circuit is shown in Fig. 3 (b).

The steps by which a discontinuity of this kind may be compensated can be visualized readily by means of the transmission line chart. A form applying particularly to the case at hand is shown in Fig. 4. All components of admittance have been normalized against the characteristic admittance of the guide. Since various points on the chart represent specific values of normalized admittance and since the matched condition corresponds to the case in which the transverse susceptance (normalized) is zero and the normalized conductance is unity, match will correspond to a point at the center of the chart.

Initially, we shall assume that we have no knowledge of the location of the discontinuity nor of its magnitude and sign. However, it is assumed that measurements made in the guide somewhere to the left of the discontinuity have indicated that a standing wave prevails and that its amplitude is that specified by the circle abcd of Fig. 4. Since this circle is also the locus of apparent admittances as viewed from various points on the generator side of the discontinuity, we

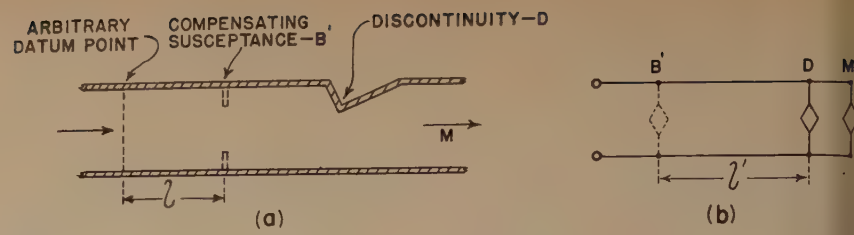


Figure 3 — (a) Schematic representation of a hypothetical discontinuity and its compensating susceptance; (b) equivalent network.

have already acquired considerable information about the discontinuity itself.

Of particular interest in our measurements are the points along the waveguide where maximum or minimum voltages prevail. They are represented by a and c on the standing wave circle of Fig. 4. Starting with a as a point of reference and continuing clockwise around the circle, we reach a point b where the apparent conductance is unity, but it is associated with a susceptance of + i1.2. Continuing around the circle of constant standing wave ratio, we pass through c to a point d where the discontinuity again appears as a normalized conductance of unity, but this time the associated normalized susceptance is —i1.

It will be observed that, for the rather arbitrary conditions assumed at points c and d, the resistance component of the load (normalized) is transformed to unity. Hence at either of these points we may supply the appropriate compensating admittance and thereby transfer the operating point to the center of the figure which corresponds to the condition of match. Since at b the total normalized admittance is 1 + i1.2, the required compensating susceptance will be — i1.2. At d the compensating susceptance will, for similar reasons, need to be + i1.2. The required su

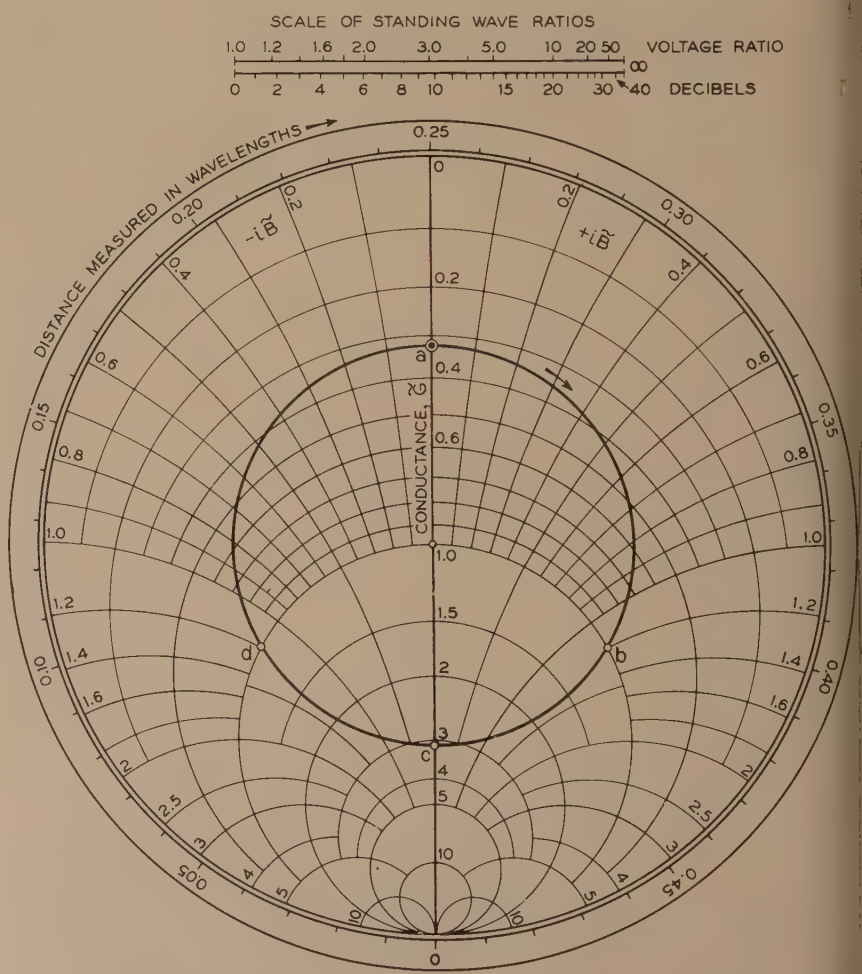
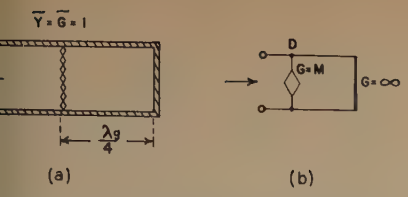


Figure 4 — Diagram showing the standing wave ratio and locus of possible input admittances produced by a discontinuity in a waveguide.



ure 5 — (a) Schematic representation a waveguide terminated in its charac-istic admittance; (b) equivalent circuit.

otance for use at point b may be inductive rod or an inductive iris. e required susceptance for use at int d could presumably be the ca-citive type of iris.

Matching by means of localized re-ors forms the basis of a very gen-l class of transformers. In contrast h the case just cited in which the continuity may have been intro-ced inadvertently, there are others which the discontinuity is an inher-property of a piece of apparatus forming some very useful purpose. r example, the discontinuity may be ociated with a receiver located at end of a waveguide line on which is desired that an optimum of sig-power be impressed. In this case ransformer is needed to match the eiver to the guide.

At first sight it might appear pos-le to follow ordinary low-frequency ctice and cut the waveguide line the proper point and connect the eiving element directly across its en end. It might be argued that, the admittance of the receiver tches the characteristic admittance the line, no transformer will be ded. It turns out, however, that the en end of a waveguide has admit-ce characteristics quite unlike those he open end of a conventional low-quency transmission line; for, in ad-ion to a susceptance component, idental to reflections from the open l of the waveguide, there may also a substantial conductance compo-t associated with radiation into the en space beyond.[3] For this reason, simple procedure followed in the eline case is not applicable to wave-des. We may, however, follow a newhat different procedure and ac-nplish the same result. This is done adding to the open end of the line quarter-wave section of waveguide ed at one end by a metal plate. s avoids radiation and at the same time produces, at the quarter-wave point, a transverse susceptance of zero, thereby approximating the characteristics of an ideal open-end line. If now we connect across the guide at this point the receiver which we will assume is effectively a pure conductance equal to characteristic admittance ($\bar{G} = 1$), we shall have met the conditions for match.

A receiver of the kind suggested is shown schematically in Fig. 5. In the interests of simplicity, we assume temporarily that it consists of a rod or film of conducting material connected transversely across the guide. Fig. 5 (b) is the equivalent circuit.

The r-f characteristics of this rudimentary form of receiver may be understood from an admittance diagram analysis of the kind shown in Fig. 6. The path around the periphery of the chart, beginning at a at the bottom and continuing to b at the top, corresponds to the transformation of the extremely high conductance of the endplate into a very small conductance at the quarter-wave point. Adding at this point a transverse conductance equal to the characteristic conductance of the guide leads us along the path bO directly to the center of the figure, the condition of match.

In practice, it may not always be feasible to provide a normalized conductance of exactly unity. Instead some value much smaller or much larger may need to be accepted. These inappropriate values may be transformed to unity by methods similar to those discussed in connection with Fig. 4.

An arrangement for bringing this about is shown schematically in Fig. 7. Its behavior may be understood from

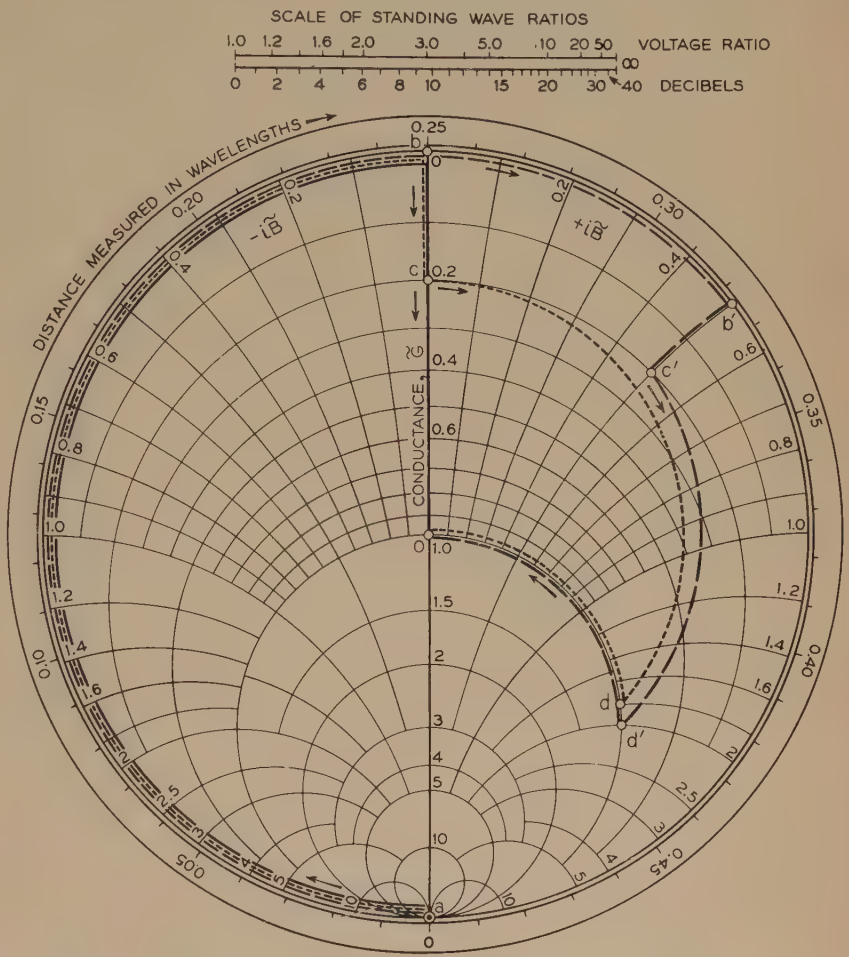


Figure 6 — Diagram showing how various discontinuities when placed across a waveguide may be matched: (1) the discontinuity is a pure conductance $\bar{G} = 1.0$ (solid line); (2) the discontinuity is a pure conductance $\bar{G} = 0.20$ (dotted line); (3) the discontinuity is an admittance $\bar{Y} = 0.20 + i0.5$ (dashed line).

e differences between a two-wire transmission line and its aveguide counterpart are not as great as here implied. If in e wire-line case we make the wire separation comparable with one wavelength, reflection effects will be observed at the open end that are quite comparable with those prevailing in waveguides.

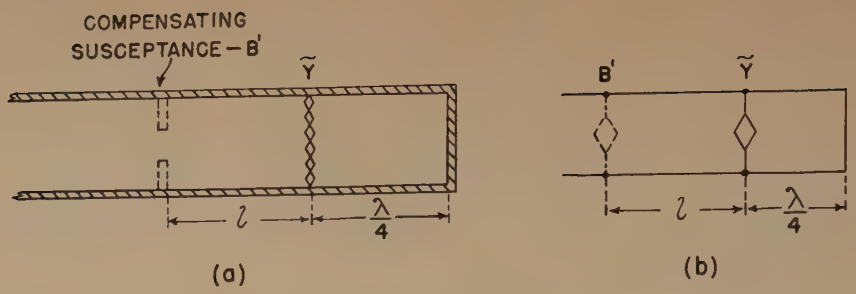


Figure 7 — (a) Schematic representation of cavity matching in a waveguide; (b) equivalent circuit.

the admittance diagram shown in Fig. 6, where it is assumed that the transverse element placed across the guide is a pure conductance of magnitude $\overline{G} = 0.20$.

Beginning again at the endplate, the path is, as before, clockwise around the periphery of the diagram from a to b. This time, however, the added conductance being 0.2, it continues via the dotted line from b to a point c and not to the center of the figure as before. To reach the center of the figure which corresponds to match, the correct path is clockwise along a circle of constant standing wave ratio from c to d, at which point the normalized conductance of 0.20 is now transformed to unity. This distance is approximately $l = 0.18\lambda_g$. Since, in this process, a susceptance of $\overline{B} = i1.8$ has been incurred, we must add across the guide at this corresponding point a compensating susceptance of $B' = i1.8$ in order to be carried along the path dO back to the center of the figure. The added susceptance may be an inductive iris. As will be noted from Fig. 7 (a), the iris and the closed waveguide at the right constitute a kind of resonant chamber. Accordingly, the method is sometimes referred to as cavity matching.

In a case even more general, the load may be inappropriate not only as regards conductance but as regards susceptance as well. The load, for example, may be represented by an admittance of $\overline{Y} = 0.2 + i0.5$. The path on the admittance diagram leading to match is again around periphery of Fig. 6 from a to b. If, at this quarter-wave point, the admittance $\overline{Y} = 0.2 + i0.5$ is connected across the guide, the operating point will be shifted to c'. The path then continues along a circle of constant standing wave ratio to d' where the apparent susceptance is $\overline{B} = i.2$. A compensating susceptance $\overline{B} = -i2$ now provides a path d'0 to the center of the figure.

Inspection of Fig. 6 shows that, for the particular example chosen, the incorporation of a susceptance component in the load has not altered the electrical distance back to the endplate, but it has altered markedly the distance to the compensating susceptance $\overline{B}'$. Also, it has altered somewhat the magnitude of the susceptance B'. A further study of the problem wi show that the particular path chose is not unique. The number of path is infinite, and each corresponds to different combination of chambe length with magnitude and positio of the susceptance $\overline{B}$.

We have assumed in the foregoin discussion that the receiver to b matched is a relatively simple struc ture consisting of a transverse rod c film connected symmetrically acros the guide. Although these rather idea ized loads may be approximated i practice, more often the ultimate re ceiver is a small crystal in which large part of the absorption actuall takes place in a very restricted regio It is common practice to mount thes crystals in ceramic cartridges with ap propriate connections to opposite side of the waveguide. Since the length c the connectors may be an appreciabl part of a wavelength and the cerami shell may appear as a capacitanc shunting the crystal, it is evident tha the load as seen from the walls of th guide will in general be complicate For this reason, match is usually ar rived at by experiment.

We are grateful to the D. Van Nostrand Co., Inc. for the use of material in this article drawn from the book, PRINCIPLES AND APPLICATIONS OF WAVEGUIDE TRANSMISSION, authored by Dr. George C. Southworth; and to the Bell Telephone Laboratories for the use of their material.

DR. SOUTHWORTH HAS PREPARED ANOTHER TWO-PART SERIES ON THE SMITH DIAGRAM WHICH WILL APPEAR SOON IN SUBSEQUENT ISSUES OF "THE MICROWAVE JOURNAL."

TEMPERATURE COMPENSATION OF FERRITE ISOLATORS . . . . . .

Temperature compensation of a ferrite isolator may be accomplished by the use of a low Curie temperature material external to the waveguide. The low Curie material acts as a temperature variable element to increase or decrease the applied magnetic field as required by the isolator configuration.

BY

GERSHON WHEELER

AND

PAUL RAJCOK

SYLVANIA ELECTRIC PRODUCTS, INC.

Microwave ferrites, along with other magnetic materials, have a Curie temperature, at which they lose all magnetic properties. The saturation magnetization, $4\pi M_s$, changes gradually with temperature, becoming zero at T_c, the Curie temperature. If the ferrite is to be used in a controlled environment at low power, there is no problem. But in general, ferrite isolators are used in systems requiring operation over broad ambient temperature ranges, and in addition the isolators themselves absorb power which causes a further temperature rise. Figure 1 shows the temperature rise for a typical X-band isolator dissipating 20 watts at room temperature and at 125° C ambient. The ferrite in the isolator was mounted on a piece of dielectric with no contact to the metal walls of the waveguide. Temperature was measured by means of a thermocouple fastened directly to the ferrite.

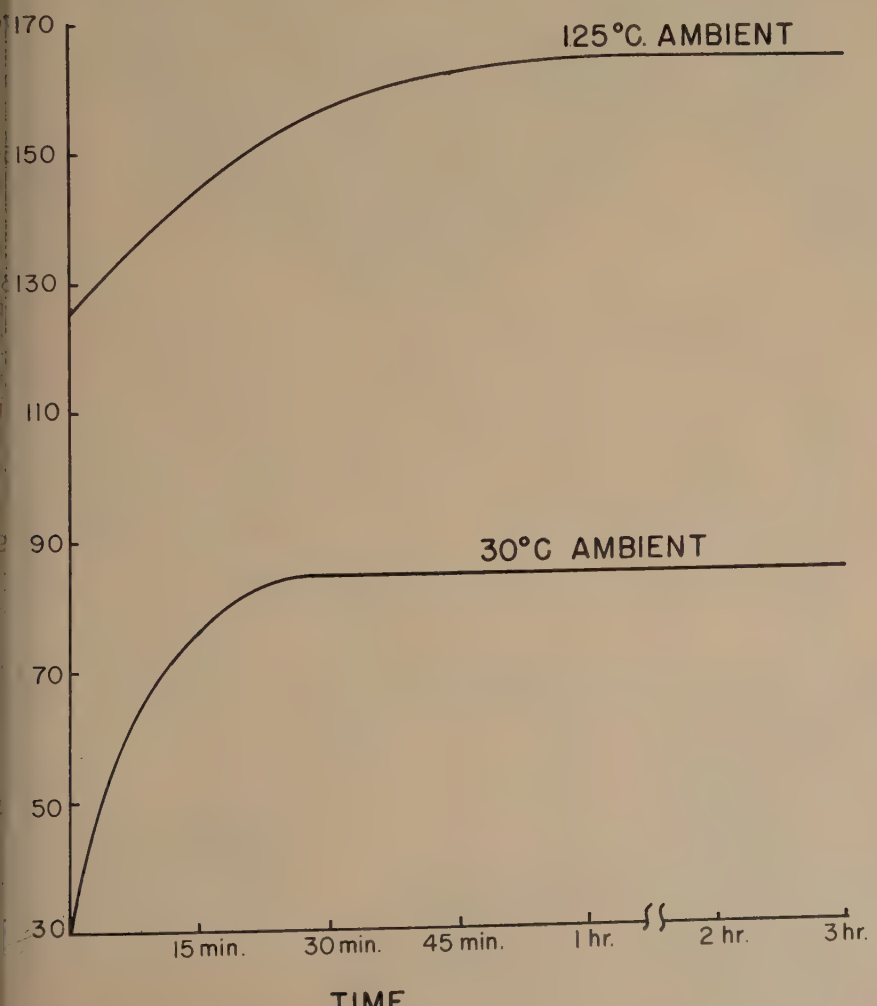


Figure 1 — Temperature rise vs. time for isolator dissipating 20 watts.

The temperature change causes a change in the $4\pi M_s$ of the ferrite. As a result, the external magnetic field, which was designed for operation at a particular frequency at room temperature, causes resonance at a different frequency at elevated temperatures. In particular, in an E-plane isolator with constant applied magnetic field, a temperature rise causes a shift in peak resonant frequency downward. This may be corrected by an increase in external field. Similarly, in an H-plane isolator, a temperature rise causes an upward frequency shift, which may be corrected by a reduction in applied field.

Previously tried methods of compensating for the temperature change use tapered magnetic fields or other means to make the isolator cover a broader band of frequencies than required. Then, even with a frequency shift, the isolator is still within specifications in the narrower frequency range. These methods have the limitation that in order to get the broader band necessary at lower temperatures, it is necessary to compromise performance over the frequency band of interest.

The present method of compensation uses external low Curie temperature ferrites to change the magnetic field in the desired direction as the temperature increases. In an E-plane isolator, as mentioned above, it is desired to increase the field as the temperature rises. This is done by shunt compensation, as indicated in Fig. 2. The magnet is charged to a value higher than necessary for resonance at room temperature. Then the low Curie temperature compensating material is shunted across the field as shown to reduce the field in the ferrite to the required value. As the temperature increases, the compensating material reaches its Curie temperature and ceases to act as a magnetic shunt. Thus the field in the ferrite is increased.

An H-plane isolator may be compensated by the series method shown in Fig. 3. Here, the pieces of compensating material act as pole pieces at room temperature. As the temperature increases, they lose their magnetic properties and become effectively air gaps in the magnetic field, causing a reduction of the field in the ferrite.

Figure 4 shows the measured change in field with temperature at the center of the gap of a shunt compensated magnet. Figure 5 shows the change in field of the same magnet with series compensation. The magnet gap size and cross-section of the compensating elements are indicated on the figures. The compensating material was Trans-Tech 414 ferrite which has a Curie temperature of about 100° C. The magnet without compensation was charged to 1250 oersteds in both cases.

Experimental results are indicated in figures 6 and 7. Figure 6(a) shows the shift which occurred in a small X-band E-plane isolator without temperature compensation. Figure 6(b) shows a shift in the opposite direction with a shunt of two pieces of TT 414, ¼″ × ¼″ in cross-section. Here it is obvious that the isolator has been overcompensated. However, the specification of 10 db isolation is met.

Figure 7(a) shows a C-band isolator with too great a shift when uncompensated. The compensation in Fig. 7(b) was furnished by two ½″ × ¼″ blocks of TT 414 and is almost exactly correct.

In general, the compensation can best be determined experimentally. It is impossible to compensate exactly over a large temperature range, and some variation must be tolerated. But if the compensation is designed for the extremes of the specified temperature range, the variations may be held within permissible limits.

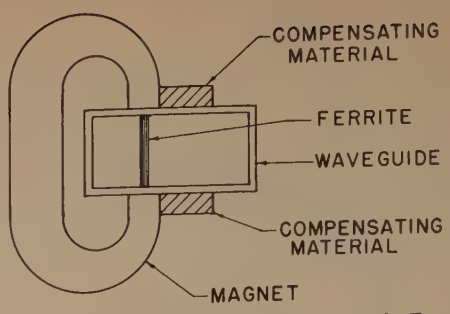


Figure 2 — Shunt compensation of E-plane isolator.

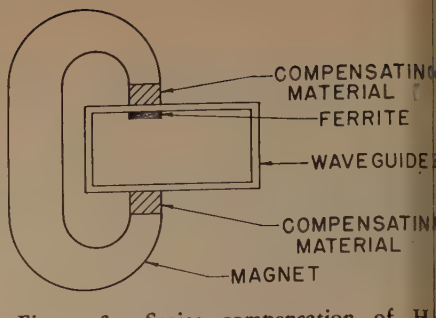


Figure 3 — Series compensation of H-plane isolator.

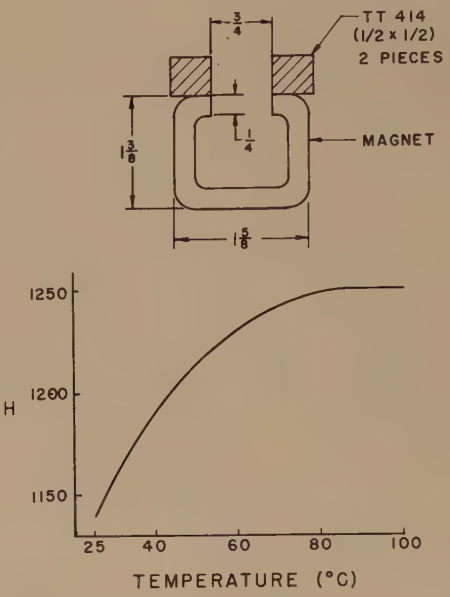


Figure 4 — Change in field vs. temperature for a shunt compensated magnet.

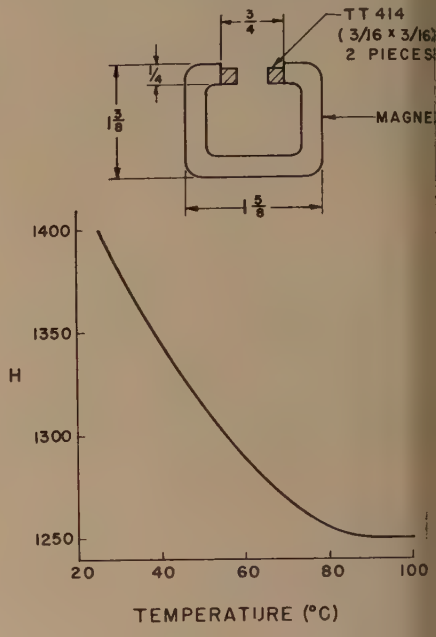


Figure 5—Change in field vs. temperature for a series compensated magnet.

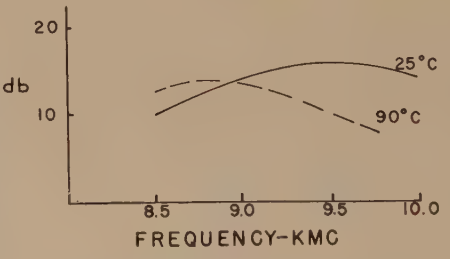


Figure 6(a) — No compensation.

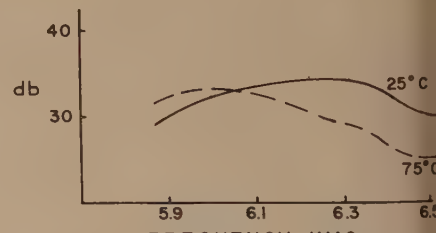


Figure 7(a) — No compensation.

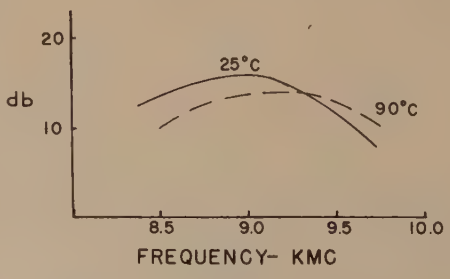


Figure 6(b) — Over-compensated.

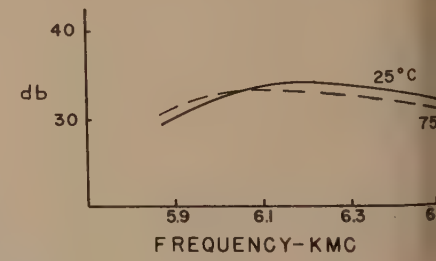
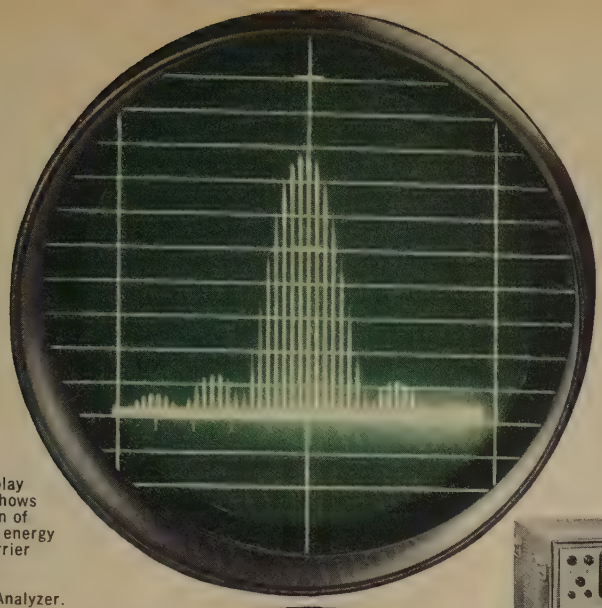
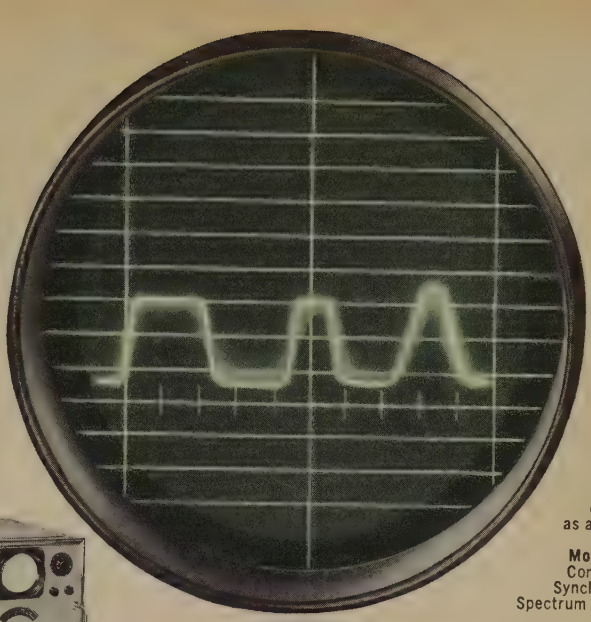


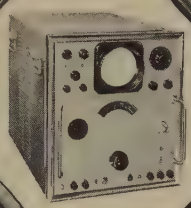
Figure 7(b) — Under-compensated b nearly correct.

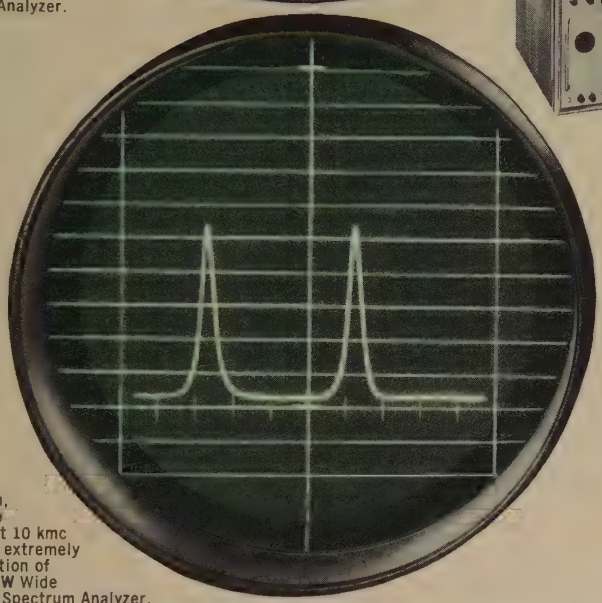


Visual display instantly shows distribution of microwave energy around carrier frequency. **Model TSA** Spectrum Analyzer.



Pulsed signal displayed as a function of time. **Model TSA-S** Combination Synchroscope-Spectrum Analyzer.





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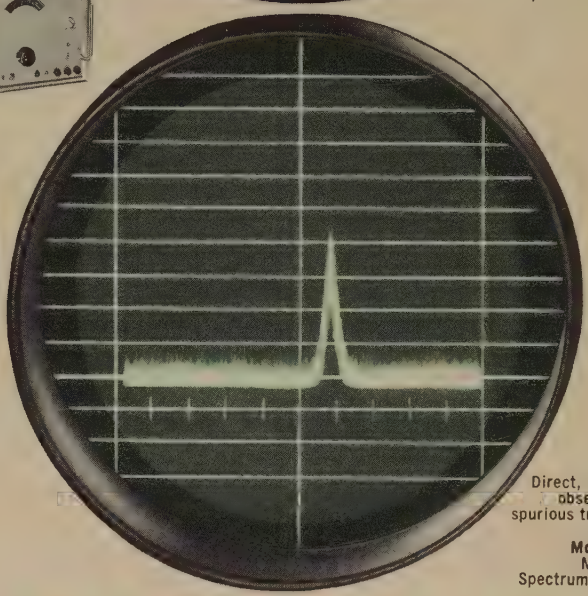

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1959 PGMTT NATIONAL SYMPOSIUM

The Professional Group on Microve Theory and Techniques, Boston tion, in cooperation with the Divin of Engineering and Applied Phys- Harvard University, announces:

The 1959 PGMTT National Symposium

ce: Harvard University, Paine Hall, Cambridge, Mass.
ne: June 1 - 3, 1959
gram: Six technical sessions, morng and afternoon. Banquet, June nd, 7:30 p.m., Cocktail hour, :30 p.m.

Professor E. M. Purcell
Harvard University

The 1959 PGMTT National Symium is scheduled to be held Mon through Wednesday, June 1 - 3, 59, at Harvard University, Camdge, Massachusetts. Three days of hnical sessions covering the latest vances in Microwave Theory and chniques and Microwave Compots, Physics, and Systems, will pro- le one of the most extensive and nprehensive technical programs of year.

Six technical sessions will be held th a welcoming address by Dean George Bundy, Dean of the Facy of Arts and Sciences of Harvard iversity. Invited speakers will pre- t papers concerned with the latest vances in parametric amplifiers, sers, ferrites, and other areas of rent interest.

Social activities will center around the Tuesday evening cocktail hour and banquet. The banquet Master of Ceremonies will be Mr. W. L. Pritchard. The banquet speakers will be Professor Harvey Brooks of Harvard; and Professor E. M. Purcell, the principal banquet speaker.

In addition a ladies' program is being organized to avail to the women the many historical and cultural points of interest within the Boston area.

The Technical Program Committee announces that the deadline for submission of papers has been moved up to March 1, 1959.

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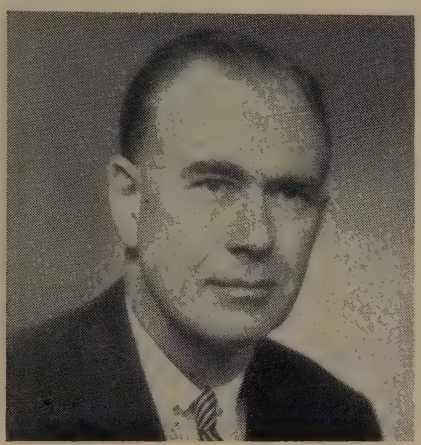
ROBERT E. LEWIS NEW SYLVANIA PRESIDENT



Robert E. Lewis has been elected President of Sylvania Electric Products Inc., the Company's Board of Directors announced recently. Previously he was a Senior Vice President of the company.

As President, Mr. Lewis succeeds Don G. Mitchell, who will continue as Chairman of the Board. On November 6, 1958, the boards of directors of General Telephone Corporation and Sylvania voted approval, in principle, of the merger of Sylvania into General Telephone. Under the merger plan, it is contemplated that Mr. Mitchell will become President of the combined company which will be known as "General Telephone and Electronics Corporation."

Mr. Lewis assumed his new duties January 1st, with his headquarters at Sylvania's executive offices in New York City. He is a Director of Sylvania. While a Senior Vice President, Mr. Lewis served as President of the Company's Argus Cameras Division and had responsibility for the operations of the Semiconductor Division.

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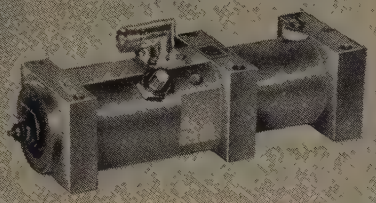
NEW



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POWER OUTPUT 1.5 KW peak minimum at .001 duty cycle, 1 μsec pulsewidth, 1000 pps

TUBE GE 6442 triode

OPERATING CONDITIONS 3000 V at 2.5 amp peak (Nominal) Heater 6.3 V ac or dc (5%)

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SHOCK 70 g while operating (frequency shift 1 MC max.)

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CIRCLE READER SERVICE CARD 13

Persons . . . . . Places

KLUENDER HEADS MILITARY SYSTEMS GROUP AT G.E.

General Electric's Communication Products Department has named Edward C. Kluender as Manager of Military Systems Engineering.

In his new position, Kluender will coordinate systems planning for the G-E military communications group, defining components to be developed and integrated into final products.

Kluender has been with General Electric since 1938 and has had wide experience in engineering military and commercial communication equipment. He has worked on the design of G-E transmitters for several Navy projects and has also contributed to the design of several radars, tank sets, and military microwave equipments.

A graduate of Texas A&M, Kluender is a senior member of the Institute of Radio Engineers and has been active in RETMA.

• • •

D. S. KENNEDY NAMES J. T. de BETTENCOURT AS VICE-PRESIDENT FOR RESEARCH & DEVELOPMENT

The appointment of Dr. Joseph T. de Bettencourt as Vice-President for Research and Development was announced recently by Donald S. Kennedy, President of D. S. Kennedy & Company.

In this newly created post, Dr. de Bettencourt will be responsible for the activities of the company in the field of advanced electronic research for the direction of Satellite-Kenne Inc., the company's West Coast search laboratory. By means of appointment, therefore, the resea efforts of the company, which is am the world's foremost designers fabricators of large antennas, incl ing radio telescopes, missile-track antennas, and microwave communi tion installations, will be largely c solidated under one group.

• • •

POTE NAMED FELLOW OF THE IRE

Alfred J. Pote, Executive Vice-Pr ident, Hycon Eastern, Inc., Cambrid Mass. has been named a Fellow of Institute of Radio Engineers (IRE The grade of Fellow is the high membership offered by the IRE and bestowed only by invitation on th scientists and engineers who have ma outstanding contributions in radio a allied fields.

Mr. Pote's citation reads, "For c tributions to high power accelerat radio frequency heating and commu cation systems."

At Hycon Eastern, Mr. Pote ex cises complete technical supervision all telecommunications programs. H con Eastern has designed telecomm nications systems for the NATO N tions and countries in Southeast A and North Africa. The company h recently been retained as consulta by Norway.

• • •

JAMES R. LEWIS APPOINTE PUBLIC RELATIONS DIRECT FOR THOMPSON RAMO WOOLDRIDGE INC.

Los Angeles, Calif., Jan. 29 — A pointment of James R. Lewis to newly-created corporate staff p tion of director of public relati for Thompson Ramo Wooldri Inc. was announced today by Dean E. Wooldridge, president.

Lewis was formerly director of information staff of Ramo-Wo dridge, a division of Thomp Ramo Wooldridge Inc. responsible for corporate public

In his new position, Lewis will lations and advertising activities p taining to the TRW corporation a whole and the coordination these functions within the compa Cleveland and Los Angeles op tions.

VARIAN AND BOMAC COMBINE OPERATIONS

alo Alto, Calif., Jan. 20—The rd of Directors of Varian Asso- es, electronics development and ufacturing firm of Palo Alto, Cal- nia, announced today that negotia- s have been completed, subject to settlement of legal and account- matters, whereby Varian Asso- es and Bomac Laboratories, Inc., Beverly Massachusetts, will com- operations through an exchange ommon stock with Varian acquir- an 80% interest in Bomac and ng an option to acquire the bal- of the outstanding Bomac com- stock.

les for Varian Associates for the ending September 30, 1958, have reported at $19,543,232 and net ings at $1,225,364. Bomac sales 1958 are estimated at $10 million earnings, for the same period, of oximately $450,000.

omac Laboratories, Inc., was ded in 1947 by Henry J. McCar- President, and Harold C. Booth, cutive Vice President of the elec- ics company. It has had a remark- growth record. Starting with t employees in a 1500 square building it now employs 740 ple and occupies a modern 130,- square foot plant in Beverly.

cCarthy and Booth, will continue ead the operation of Bomac Lab- ories, Inc., and will join the ian Board of Directors upon com- ion of the exchange of stock. Mr. th will be elected a Vice Presi- of Varian Associates.

arian Associates was founded in 3 by Russell and Sigurd Varian, several associates. The Varian hers are the inventors and develop- of the klystron tube which was in most World War II radar re- ers. Beginning with a small group engineers, Varian now is stated e the world's largest producer of tron tubes. It is engaged in the lopment and production of micro- e tubes and components for use elevision and communications, for al navigation, traffic control and ughout the defense establishment.

arian employs over 1500 persons ts plants in Palo Alto, California Georgetown, Canada. Its prod- and services, Stearns said, are sold world-wide basis.

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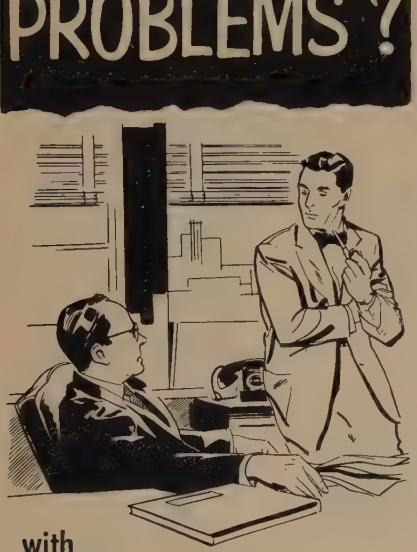

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- QUALITY
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It is easy to eliminate all these problems when you call on CUSTOM COMPONENTS Inc. because

CUSTOM COMPONENTS Inc. is the largest and most diversified Manufacturer of RADIO CORES & MICROWAVE COMPONENTS stressing "Quality, Economy and Service."

Our production facilities will assure you of deliveries co-ordinated with your needs. Our engineering department will cooperate with you in planning the proper material and shapes to fill your specifications and needs.

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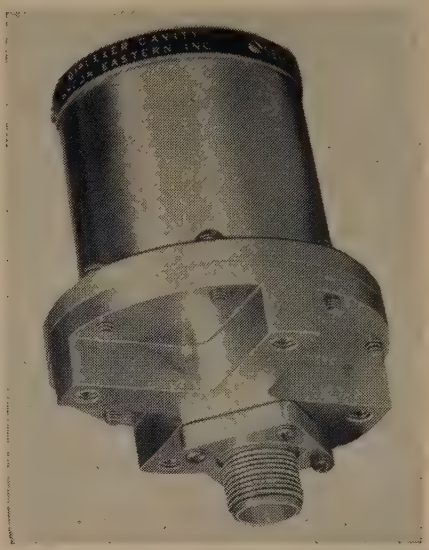
NEW PRODUCTS

NEW HIGH POWER TELEMETERING DIPLEXERS FOR SEVERE ENVIRONMENT



Hycon Eastern, Inc., Cambridge, Massachusetts has just announced new High Power Telemetering Diplexers, Type 1231. These instruments feed signals from 2—100 watt transmitters into a single missile antenna system and are designed to satisfy military requirements for use in test missiles and supersonic aircraft for telemetering.

Environmental Specifications are: shock to 100 G, vibration to 20 G at 2000 cycles, temperature —70°F. to 350°F. Units made of Invar may be provided at extra cost for use up to 500°F.

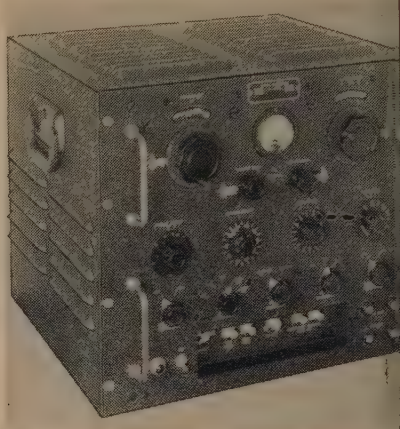
CIRCLE READER SERVICE CARD 101

• • •

HIGH LEVEL SIGNAL GENERATOR FEATURES LOW LEAKAGE, CONSTANT OUTPUT TO 10 WATTS

Excellent stability and constant high-level output of pulse-modulated R-F signals in the 10 cm band over a frequency range of 2700 to 3000 megacycles are features of a high-precision signal generator, announced by BJ Electronics, Borg-Warner Corp. Output of the instrument is internally monitored, continuously adjustable to as much as 10 watts peak, and indicated by a meter mounted on the front panel. Controls are direct reading, eliminating the need for calibrat charts.

The Model 80 High Level Sig Generator comprises three basic un the modulator, the R-F section, the power supply. The R-F sectio controlled by the modulator u which, in turn, may be governed external modulating or synchroniz signals. However if external sig are not used, the modulator can p vide its own modulation and s chronization. Continuous meter ir cation is available for any duty cy within the range of the instrume with a standard duty cycle provi for normal calibration.



Other specifications listed for Model 80 unit include: accura ± 0.25 percent; resettability, ± 0 percent; stability, ± 0.03 perce pulsed R-F output, + 40 dbm (watts peak) to — 80 dbm, exte able to — 120 dbm, with output c tinually monitored and constant o the full frequency range. The inst ment is designed for either relay r or instrument case mounting.

CIRCLE READER SERVICE CARD

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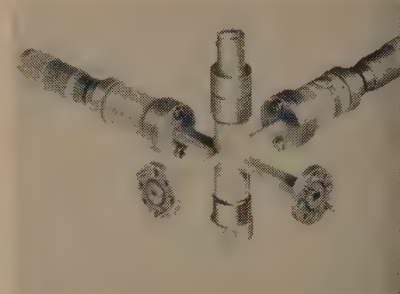
140 KMC MICROWAVE EQUIPMENT AVAILABLE FRO DE MORNAY-BONARDI



Equipment for the generation, tection, and measurement of mi wave power up to 140 KMC is in production at De Mornay-Bona Pasadena, Calif.

A complete line of 140 KMC equipent is supplied and includes crystal ultipliers, crystal mounts, E-H tun-, cavity wavemeters, standing wave tectors, attenuators, elbows, twists, minations, standard gain horns, ovable shorts, and magic tees.

Designed for performing precision easurements, each instrument is a ecision unit and is the result of a ogram of extensive research and dellopment which was necessary in der to attain the exacting requirents characteristic of these extremely ort wavelength equipments. Accordg to De Mornay-Bonardi, these inuments are functionally as accurate D-B equipment used at 90 KMC. l units are laboratory tested for opnum performance and are available 45 day deliveries. Complete data is ailable on request.

RCLE READER SERVICE CARD 103

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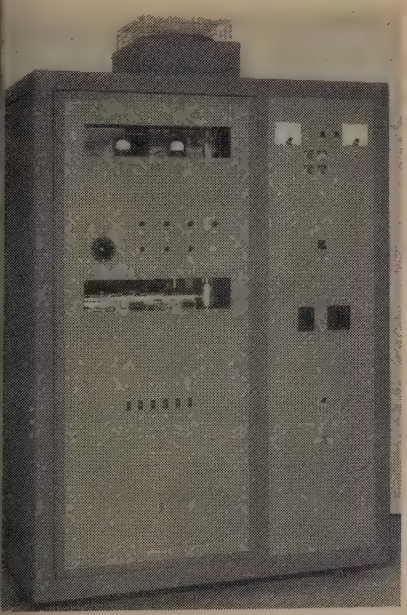
HIGH-VOLTAGE HARD-TUBE PULSE MODULATOR

The Levinthal Model 70M hardbe, high-voltage pulse modulator a flexible tool for experimental be testing. It is capable of two disctly different modes of operation: thode pulsing and modulatingode pulsing. In both modes, it opates anywhere in the range from cps to 12,000 cps and with pulse ngths continuously variable from 5 to 30 microseconds.

As a cathode pulser it will pulse om 0 to 35 kv up to 10 amp. As



modulating-anode pulser, it will ulse from 0 to 35 kv into a 25 $\mu\mu$f ad.

Equipment consists of one cabinet containing a 35-kv 0.1 amp power supply with less than 0.1 per cent peak-to-peak ripple, a 0- to 20-volt, 0- to 20-amp filament supply for the tube under test and a special pulse-modulator unit capable of being switched to two modes of operation. Included in the equipment is a special spark-gap crowbar system which will operate anywhere from 0 to 65 kv for high-speed protection of the load. This circuit is designed to be fail-safe and to be triggered from either an excessive current pulse or by any pulse occurring during the normal interpulse pulse period. Included in the system is a self-contained trigger generator with three delayed outputs variable from 0 to 35 microseconds each. All of the necessary meters, controls, interlocks, indicators, and safety features as required are provided. Critical waveforms are brought to a monitor selector switch for oscilloscope viewing.

Total power requirement is about 10 kva from a 440-v, 3-phase, 60 cps source.

CIRCLE READER SERVICE CARD 104

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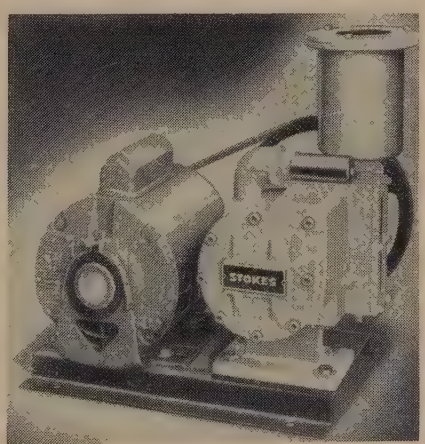
NEW STOKES 2 AND 3 CFM. COMPOUND VACUUM PUMPS

The Vacuum Equipment Division of the F. J. Stokes Corporation, Philadelphia has just introduced a new series of compound high vacuum pumps. The new pumps are compact and light, but sturdy; and provide highly efficient pumping free from noise, vibration, and oil fumes.



The new Stokes Compound Pumps, offered initially in two sizes: SC-2, of 2.3 cfm. displacement, and SC-3, of 3.7 cfm. displacement, are capable of providing rapid pumping and an ultimate blankoff pressure of 0.1 micron.

CIRCLE READER SERVICE CARD 105

TEST INSTRUMENTS for *LABORATORY/PRODUCTION*

Sensitive Detection of Microwave Energy

PRECISION TEST RECEIVER

The AIL Type 130 Precision Test Receiver (30 and 60 Mc standard units available) is a versatile instrument combining a high gain, low-noise figure receiver and a secondary standard of attenuation. It can be used wherever accurate measurements of the differences of r-f and i-f power levels are required. A few typical applications are: noise-figure measurement, measuring characteristics of directional couplers, calibration of r-f attenuators and measurement of selectivity characteristics.

Detailed literature is available on request.

AIRBORNE INSTRUMENTS LABORATORY
A DIVISION OF CUTLER-HAMMER, INC.
1345 NEW YORK AVENUE
Huntington Station, L. I., N. Y.

CIRCLE READER SERVICE CARD 15

TR DEVELOPMENT ENGINEERS

You are cordially invited to discuss your future with one of the most accomplished research and development teams in the field of microwave devices.

The man we seek should have a degree in Electrical Engineering or Physics. He should offer at least two years' experience in Microwave Theory and Design, Gas Discharge Theory and Microwave Testing and Circuitry, including circuitry and measurement techniques.

You will join a team engaged in studies involving high power gas discharge phenomena and high power duplexer design for most efficient system performance. Tube characteristics are also studied over a wide range of environmental conditions such as temperature, shock, vibration, etc. The objective is reliable and improved performance in switching and crystal protection over an extended tube life.

Opportunities exist for expansion into other areas involving the interaction of electromagnetic energy with various di-electric materials such as ferrites and semiconductors.

Microwave Associates ranks high among the few companies devoting a major research effort to switching devices. We have demonstrated record growth, very liberal benefit programs for our 300 employees and a new modern plant offering the finest facilities to advance your work.

Contact
Dr. Jerome Kornreich at

MICROWAVE
ASSOCIATES INC.
BURLINGTON, MASSACHUSETTS
Telephone: Browning 2-3000

HUGHES AIRCRAFT CO. ANNOUNCE NEW TYPE MICROWAVE DIODE

"Noise temperatures as low as 50° above absolute zero for a diode cooled by liquid nitrogen, and only 100° above absolute zero operating at room temperature have been obtained by Hughes Aircraft Company in a high gain 3000 megacycle parametric amplifier using sample diodes of a newly developed type.

"Dr. R. A. Gudmundsen, representing the Hughes Semiconductor Division, has announced that initial production of several hundred of these diodes per week is in effect and they are immediately available to the industry. The diode is the heart of the parametric amplifier but also has other important microwave applications such as switching and harmonic generation. It is available in two rugged and hermetically-sealed versions — one for the region below 1000 megacycles and a second for the microwave region. It is reported that because of newly developed modular line production techniques, these diodes are available at a price in the same range as good microwave mixer crystals.

"It was pointed out that the exceptionally low noise performance of amplifiers using the new diode is already in a range competitive in many applications with the solid state maser, which holds the record for absolute minimum noise performance. However, the parametric amplifier does not require low temperatures for operation. The parametric amplifier does, however, have two channels of amplification, usually called the signal and idler channels, which were used simultaneously to obtain the low noise temperatures quoted above. As a further comparison, the best reported low noise microwave tubes have noise temperatures of about 300°K at 3000 megacycles, but have the advantage of single channel amplification and electrical tunability.

"The development of the Hughes diode resulted from a cooperative effort between scientists in the Hughes Research and Development Laboratories and the Hughes Semiconductor Division research team of W. Waters, S. Eng and W. Warren, Dr. Gudmundsen related. The amplifier was designed and operated by Dr. R. C. Knechtli and R. Weglein of the Hughes Research Laboratories for the noise measurements and is lated to the type of amplifier veloped by Dr. Uenohara at the Telephone Laboratories. With noise temperatures of 50°K 100°K obtained at liquid nitro and room temperatures, respectiv the 3000 megacycle amplifier gi 30 db of amplification with two m acycles bandwidth or 10 db of am fication with 25 megacycles ba width. Such amplifiers would, course, be useful in many appli tions of microwave and UHF ceivers where greater sensitivity lower receiver noise is required.

"The production models of Hughes diode, designated HP 2800 and HPA-2810 have a norm cutoff frequency of 70,000 me cycles at maximum back bias wit nominal zero-bias capacitance 2.5 $\mu\mu$f, it was disclosed. Its exc tional noise performance is attribut to its low equivalent series re tance at microwave frequencies."

CIRCLE READER SERVICE CARD

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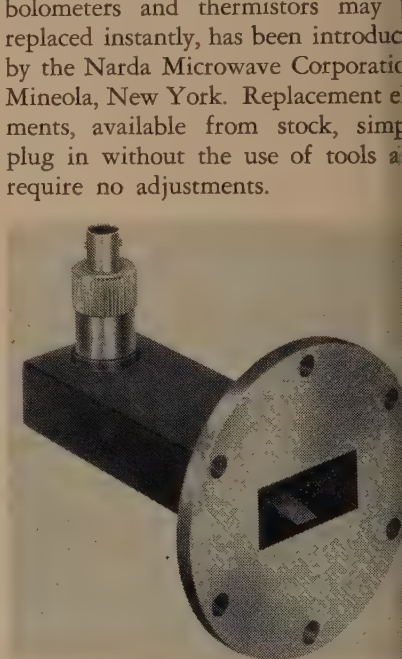
NEW FIXED TUNED BOLOMETER — THERMISTOR MOUNTS BY NARDA

A new series of matched bolome — thermistor mounts, in which bo bolometers and thermistors may replaced instantly, has been introduc by the Narda Microwave Corporati Mineola, New York. Replacement e ments, available from stock, simp plug in without the use of tools a require no adjustments.



Another advantage provided by new Narda mounts is their low VSW of 1.5 maximum, without tuning, o the full waveguide band. Four mo of the new mounts are available cover the following frequency ban 1.1 — 1.7 KMC, 1.7 — 2.6 KMC, — 3.95 KMC, and 3.95 — 5.85 KM

CIRCLE READER SERVICE CARD

Microwave Engineers

Engineers wanted with two to eight years experience in designing microwave components and instruments.

We are a progressive, expanding firm, among the top three microwave instrument manufacturers, offering full employee benefits, and 100% tuition refund plan for advanced study. Modern, air-conditioned buildings. Pleasant residential area.

Salary: Up to $13,000

Call Mr. Stuart Casper . . . PIoneer 6-4650

THE NARDA MICROWAVE CORPORATION

118-160 HERRICKS ROAD MINEOLA, LONG ISLAND, N.Y.

INDUSTRY LITERATURE

EW BURROUGHS CATALOG FOLDER

A new, short-form catalog folder of ir electronic Components and In- uments has been issued by Bur- ghs Corporation, Electronic Tube vision. The brochure contains con- sed descriptive information and lications data on Burroughs Beam tching Tubes, Nixie(R) indicator es, decade counters, pulse control ruments, optimeters, beamplexers visual decoders manufactured by company. A complete listing of re than twenty items of available rature is included on a convenient rature request card.

CLE READER SERVICE CARD 110

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NEW BROCHURE FROM EMERSON & CUMING

Emerson & Cuming, Inc., 869 shington Street, Canton, Massachu- s, announces that a new 20-page chure entitled ECCOFOAM is now ilable.

The brochure contains information both plastic and ceramic foams. se foams are used primarily in elec- al and electronic applications. The plete line covers flexible and rigid et stock, liquid foam-in-place res- artificial dielectric foams, pack- place foams for electronic embed- nt, powdered materials and an ex- sive series with adjusted electrical perties. Technical data is supplied each product.

Reprints of articles describing a iety of uses for the materials are included. Microwave lenses, ra- ne cores, void filling, circuit encap- tion, thermal insulation, packaging and re-enforcement of structures are a few applications.

CIRCLE READER SERVICE CARD 111

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PROSPECTUS DESCRIBES LATEST MICROWAVE STANDARDS MEASUREMENT TECHNIQUES

A 36-page application note describing the latest techniques and instrumentation for making various microwave standards measurements is now available from the Hewlett-Packard Company.

The booklet, "Microwave Standards Prospectus," presents a detailed description of the techniques used in the general areas of standards measurement, including frequency, attenuation, impedance and power. It contains typical measuring arrangements devised by the Hewlett-Packard standards engineering staff, with many system block diagrams and accuracy curves.

The prospectus also includes a detailed list of the latest equipment available for standards measurements.

Copies of "Microwave Standards Prospectus" are available on request.

CIRCLE READER SERVICE CARD 112

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PULSE CONTROL INSTRUMENTS

An 8-page condensed catalog of Unitized Pulse Control Instruments is available from the Burroughs Corporation, Electronic Tube Division. The booklet provides capsule technical descriptions of more than twenty-five Burroughs pulse control instruments, including pulse generators, flip-flops, coincidence detectors, delays, mixers, counters and power supplies.

The packaged units are self-contained and can be easily interconnected to form any desired pulse system. Their reliability is indicated by their successful application in the SAGE Whirlwind computer, the Burroughs UDEC computers and in countless computer, core, and radar test equipment applications.

Copies of the Unitized Pulse Control Instrument booklet may be obtained from the Burroughs Corporation, Electronic Tube Division, P.O. Box 1226, Plainfield, New Jersey.

CIRCLE READER SERVICE CARD 113

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SYLVANIA ANNOUNCES TECHNICAL BULLETIN ON GERMANIUM

A technical information bulletin which describes the physical characteristics and purity standards of germanium and germanium dioxide used in the manufacture of semiconductor devices has been made available by Sylvania Electric Products Inc.

The new booklet lists the minimum resistivity specifications of electronic-grade germanium measured with a 4-point probe at 25-degrees Centigrade; and, in addition, includes data on the specifications and chemical characteristics of the finished product.

CIRCLE READER SERVICE CARD 114

—it works

—it's accurate

—it's available

Complete data on request

DE MORNAY BONARDI

DE MORNAY–BONARDI

780 SOUTH ARROYO PARKWAY • PASADENA, CALIF.

*TRADE MARK De Mornay-Bonardi for its millimeter wave equipment

CIRCLE READER SERVICE CARD 16

SYLVANIA'S AMHERST LABORATORY

has Immediate Openings in its

NEW MICROWAVE & ANTENNA SECTION

THE MICROWAVE AND ANTENNA SECTION operates as a service function to the Laboratory in the areas of microwave component and microwave system development, microwave instrumentation, standardization, antenna development and bid and proposal preparation as related to systems.

The group will undertake problems in typical applications such as radar, communication, beacon, electronic countermeasure, navigation sets, transmission systems, instrumentation techniques and gain calibration. Development will be effected on such items as horns, reflectors, antenna assemblies, arrays, linear and circularly polarized antennas, and radomes.

Qualified engineers with a BS in EE or Physics (advanced degree very desirable) and a minimum *of 5 years experience are urged to inquire about the openings immediately available.*

MICROWAVE COMPONENTS: There is a need for development and design engineers with experience in the areas of: directional couplers, mixers, equalizers, filters, power dividers, rotary joints, special instrumentation devices.

ANTENNAS: Engineers with experience in broadband microwave antennas are needed. The group will be responsible for all phases of antenna development and design, from initial conception through prototype.

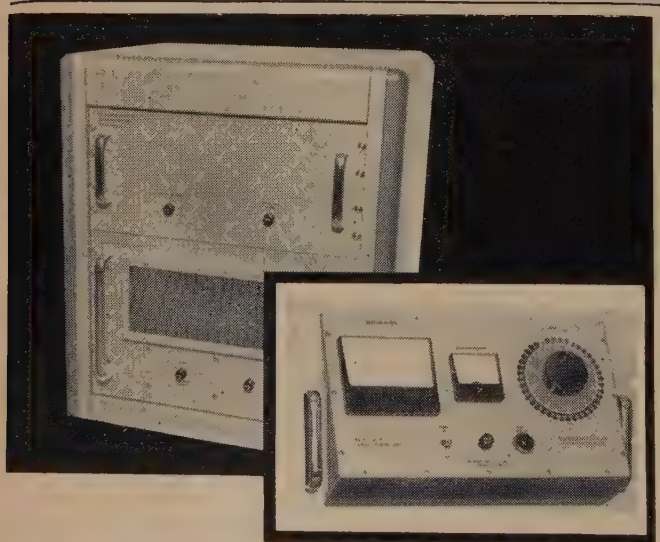
Please write to Norman C. Gibbs

AMHERST LABORATORY • SYLVANIA ELECTRONIC SYSTEMS

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.

1115 Wehrle Drive — Amherst 21, New York



MICROWAVE SIGNAL SOURCES ... REMOTELY TUNABLE

Interchangeable R.F. heads covering 1-2KMC, 2-4KMC, 3.6 – 7.2KMC, 6.7 – 11.4KMC and 8-14KMC.

WRITE FOR ADDITIONAL DETAILS TO DEPT. MJ-1

SCIENTIFIC-ATLANTA, INC.

2162 PIEDMONT ROAD, N.E. TR. 5-7291 ATLANTA 9, GA.

CIRCLE READER SERVICE CARD 17

PRECISION RADAR ANTENNA SYSTEM USE IN TRACKING TALOS MISSILE DETAILED I NEW I-T-E BULLETIN

The new radar antenna system designed for ultra-p cision tracking of the Talos missile is described in a n bulletin published by Special Products Division, I-T Circuit Breaker Company, Philadelphia.

The four-page bulletin — second in a series of en neering reports — describes details of the designing f rication and testing of a prototype antenna system specifications — all within 13 months.

The Talos antenna system is versatile, and can be eas modified. It can accommodate antennas ranging in ameter from three and one-half to eight feet. The tenna also has provision for mounting television, a ca era and a telescope.

The entire antenna system is mechanically accur to .0001 inch, with some components accurate to .0000 inch. It can be leveled to within .01 mil and can "dumped" — that is, pointed in one direction and th rotated 180 degrees to see if it lines up on the origi axis for quick checks of elevation and azimuth accura

To achieve the precision necessary for this syste I-T-E used master gears — high precision units which used as references to check the accuracy of other gear

All bearings in the system are mounted in eccent bearing sleeves so that shafts and gears can be precisi aligned.

I-T-E's Special Products Division is a principal su plier of radar antenna systems and large waveguide.

CIRCLE READER SERVICE CARD 121

EW BROCHURE AVAILABLE FOR AIRCRAFT-MISSILE ESIGNERS AND TECHNICAL MANAGEMENT

A new six-page brochure, "High cuum Technology and the Space ge," of interest to high altitude air-ft and missile industry design en-neers and technical management is ailable from National Research Cor-ration, 70 Memorial Drive, Cam-dge 42, Mass. It includes an " x 17", three-color Upper Atmos-ere Vacuum Spectrum Chart devel-ed by the NRC staff using latest ilable IGY satellite data.

The chart permits rapid determina-n of atmospheric density, tempera-e, pressure and mean free path of molecules up to an equivalent al-ude of 600 miles. For engineers ncerned with selection of equipment extreme high altitude simulation ilities, the chart also shows the rmal operating pressure ranges of ious types of vacuum gauges and mps and permits quick determina-n of effective altitude equivalents ich may be achieved in properly de-ned installations.

RCLE READER SERVICE CARD 115

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FLIGHT TEST EQUIPMENT FOR JET AIRLINERS

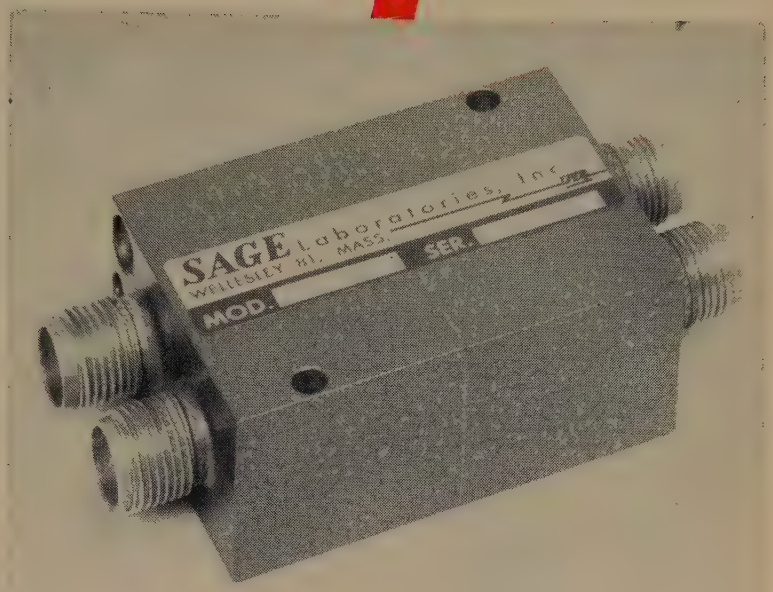
Development of the first commer-high-speed air-to-ground telemetry em for operation in the newly as-ned 1345-1465mc microwave tele-try band was announced recently by lco Corporation and Consolidated ctrodynamics Corporation.

The radio frequency equipment was igned and built by Philco's Western velopment Laboratories, Palo Alto, if., and is part of an airborne digi-data-handling system which CEC veloped for the Douglas Aircraft mpany.

Manufacturing and marketing of the air-to-ground telemetry equip-nt is being handled by Philco's Gov-ment and Industrial Division.

Built to meet environmental re-rements, the compact, airborne nsmitter has sufficient power output perate at a range of 100 miles from altitude of 5,000 feet. Greater ges are expected from the normal rating altitude of jet aircraft. The nsmitter uses frequency multiplier cuits and tuned coaxial cavities to duce output power in excess of 20 ts at any frequency within the d.

CLE READER SERVICE CARD 116



SAGE

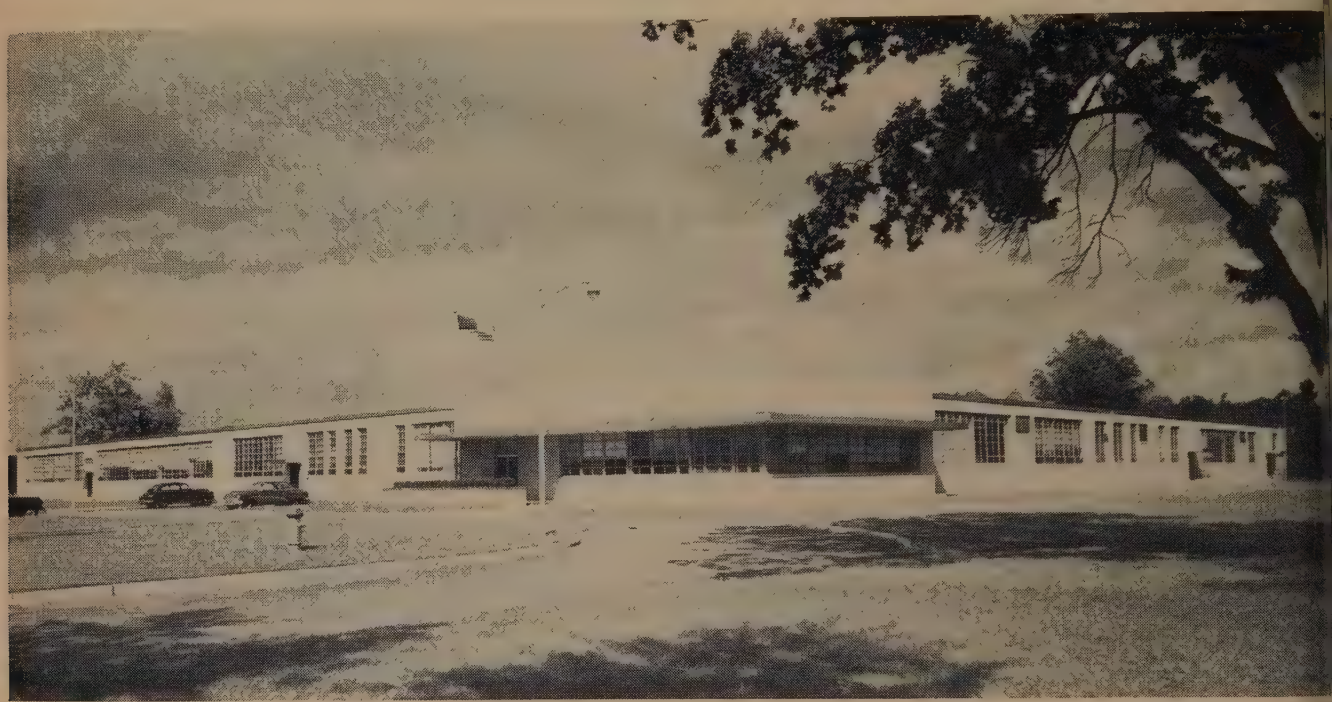
The SAGE Cobrid is the latest version of this unique device. It is designed to cover the frequency range from 8000 to 12000 mc. Coupling over this range is 3 DB ± 1.3. Isolation is at least 17 DB. The top is supplied with TNC connectors.

CIRCLE READER SERVICE CARD 18

SAGE laboratories, inc.
159 LINDEN STREET WELLESLEY 81, MASS.

When a microwave firm grows, in a little over ten years, from a five man nucleus to a complex employing nearly on thousand people — when the ideas and developments pouring out of its research department begin to swamp its strai ing facilities — when increasing customer demand adds its own pressure — then management is forced to a decision.

This recently, came upon the management at Airtron, Inc. Throughout the entire Airtron system, demand was e ceeding the supply of space, talent, equipment and resources. Airtron had to have more of these, and fast. It happen that Litton Industries, of Beverly Hills, California, was at the time looking for just such a firm as Airtron — youn thriving, with proven microwave capabilities. Litton, with complementary microwave activities of its own, had alread demonstrated abilities as a "growth-minded" organization. On August 1, 1958, Airtron was purchased by Litton. Airtro people call this event a "natural" for their company. They felt that this merger would emphasize, encourage and expedi Airtron's own phenomenal growth, and that the merger would benefit both firms. Airtron's record on its own in th short time mentioned leaves little room for doubt that the recent coalition will attain its ends. Let us look into this re ord, then, as we present this month's Company Profile, the Airtron story.



Airtron Division's Morris Plains, New Jersey plant.

PROFILE: AIRTRON, Inc.

BOX SCORE

NAME: Airtron, a division of Litton Industries, Inc.

LOCATION: Morris Plains and Linden, New Jersey; Los Angeles, California.

PRODUCTS: Flexible and rigid waveguide, microwave plumbing, load isolators, relay equipment, mechanical and ferrite switches, and mixer-duplexers.

HIGHLIGHTS: Airtron's founders sensed that, while microwave technology has been with us since 1888, it is only now entering a period of dynamic growth. The recent merger with Litton enables them to combine research, manufacturing and management resources for optimum use of manpower and facilities.

NOTE: The Editor wishes to extend his thanks to Mr. W. R. Hanawalt of Westfield, N.J., and to Mr. David Ingalls, for their assistance in assembling material for this feature. J.W.H.

AIRTRON INC. was born in 1946, and the spark tha started the company on its way was the present tion of what was then a unique problem to the company founder, David Ingalls.

Ingalls at that time was chief engineer at Titeflex, company that manufactured round flexible tubing. group of Westinghouse engineers, working on a Nav radar contract, worked out a system that required *re tangular* flexible tubing. When they presented their prob lem to Ingalls, he admits he was stumped. This was som thing new; but applying himself to the job with chara teristic vigor, and (he admits) with the help of Lady Luc he was successful in producing the first flexible waveguid of a convolution type.

Shortly after this, Titeflex sold out; but allowed Inga to take his baby, which was now a production item, a use it to be the basis of his own microwave business. Wi four other engineers, Ingalls set up his new company in abandoned schoolhouse on Staten Island. The usual pa tern then evolved — hard work, long hours, and an a celerating growth. Tore N. Anderson added his talen to the firm, although at first it was on a part time bas for the young company couldn't afford him full time! T name "Airtron" was picked — "air" for aircraft and "tro

Waveguide switch assembly line.

One of Airtron's precision machining areas.

electronics, and thus another successful company in microwave business was well underway. And, as Dave alls says, "Airtron was started as a result of our being ed to Square a circle — and we've been busy Squaring les ever since!"

ngalls graduated from Massachusetts Institute of Tech- ogy in 1934 with a degree in Mechanical Engineering. ing Titeflex, Inc., he soon became Chief Engineer and ed a major role in the growth of that company. In 6, he founded Airtron, Inc. When in 1958 Airtron me a wholly-owned division of Litton, Industries, he me a Vice-President of that organization, and continues President of Airtron, Inc.

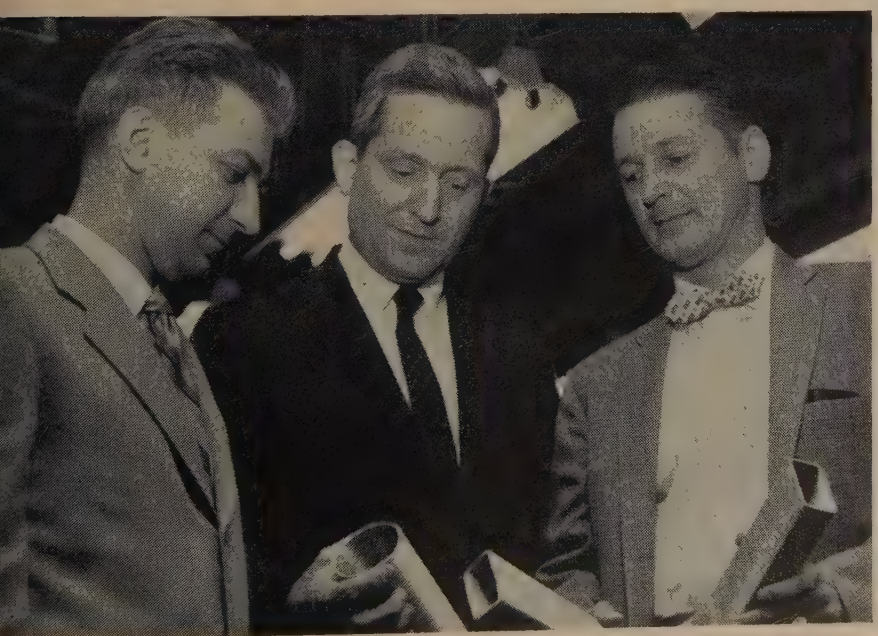
nt and Facilities

oon Airtron outgrew its schoolhouse and graduated 25,000 square foot building in Linden, New Jersey. 1949 the company needed still more space and spread in Linden to a total of 60,000 square feet. By 1958 tron had expanded into seven plants, six in Linden one in Cambridge, Mass., covering 150,000 square . At the present time, as part of the Litton group, tron has consolidated three of its divisions in Morris ns, N.J., in a new 100,000 square foot building on a acre tract and continues to operate a manufacturing set-up in Linden of 70,000 square feet in three modern buildings.

Products

While becoming a full-line microwave plumbing business, Airtron was rapidly moving ahead in the jet engine field, developing spark plug leads, junction boxes and cable assemblies for all the electrical controls of major jet aircraft production then in existence. The company's directors had a hunch that, eventually, electrical controls for jet aircraft would become obsolete. They bent their efforts to develop microwave devices ahead of their time to replace the controls then in use. This hunch paid off, as everyone now knows.

A breakdown of Airtron's production organization shows it operating in three locations—in Linden, Morris Plains and Los Angeles — each concentrating on some phase of microwave work. The Linden operation produces flexible waveguide components for microwave relay stations as well as for mobile and regular broadcast transmitters. Ships, vehicles, and aircraft also use these flexible transmission lines in their radar equipment. The Linden operation also boasts an advanced foundry specializing in precision waveguide castings — the only one of its kind in the industry.



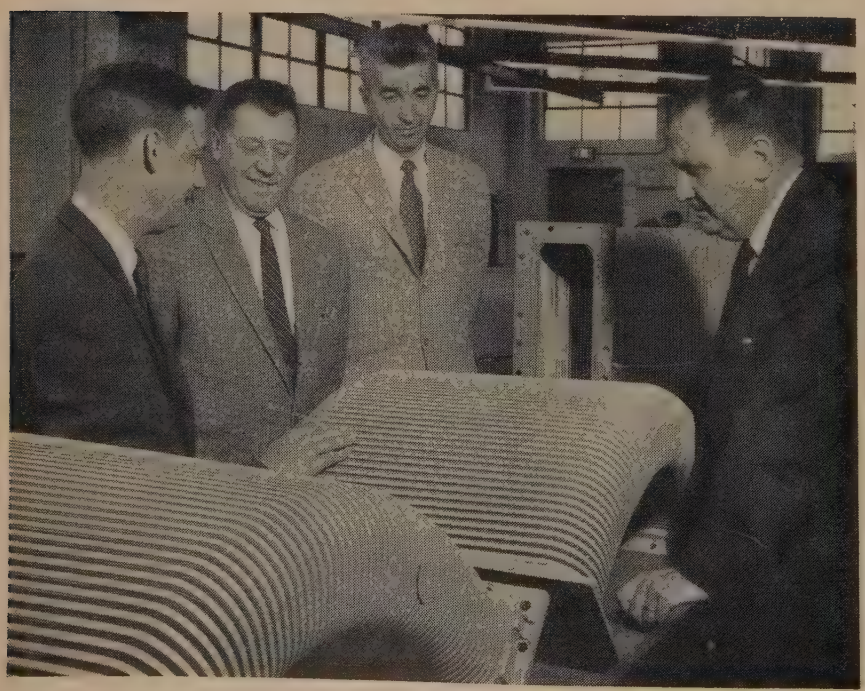
Nicholas Macula, Dave Ingalls and Robert Carr reminisce about the work they did together in the original "circle-squaring" triumph that resulted in the first convolution-type flexible waveguide. This event sparked the founding of Airtron.

The Morris Plains plant designs, develops and manufactures electronic components and equipment for the radar and avionics fields. Its engineering activities are under the direction of Tore Anderson and Dr. Ernest Wantuch. Anderson has been associated with Airtron since 1948. His experience includes wartime projects on underwater mine detectors while Chief of the laboratory and test section of the Engineering Research and Development Agency, Fort Belvoir, Va. After the war, he was engineer in charge of r-f measurements at Electrical Testing Laboratories in New York. His progress at Airtron includes appointments to Chief Engineer in 1951, Vice-President and Board of Directors in 1953, and Director of Engineering in 1956. Dr. Wantuch is Vice-President in charge of Engineering. Just prior to the recent consolidation, he was in charge of the Cambridge, Mass., division which, from 1956 to 1958, was devoted to research and development in the field of microwave ferrite devices. He came to Airtron from Raytheon's Missile Systems Division, where he was in charge of all microwave development. Morris Plains also produces directional couplers, mixer duplexers, transmission line assemblies, as well as waveguide switches, bends, transitions, and ferrite microwave components.

Since merging with Litton, a plant in Los Angeles, California is now in full production on all types of microwave devices, but specializing in ferrites and rotary joints.

The company name is found also abroad. In London, England, W. H. Sanders (Electronics) Ltd. is licensed to make Airtron flexible waveguides and supplies them to a large portion of the British Market. In Paris, France, S. A. Fenwick is producing Airtron flexible waveguide for France. Both companies also supply the German market. In Canada, the waveguide is produced by Airtron Canada, Ltd. Any of these companies can procure other Airtron products from the U.S. for special customer requirements.

Tore Anderson, Vice President, leaving on one of his many field trips, reviews last minute pointers with the boss.



George Thompson (left), Division Manager, "shows-off" the biggest waveguide ever built to three of the founders of Airtron — (left to right) William Scott, J. W. Hamilton and Bernard LeRoe.

cutives responsible for operation of the Airtron-Los Angeles Facility. Seated at the table from left to right: Ray A. Krogh, ef Engineer; Grafton P. Tanquary, General Manager; Alvin C. West, Quality Control Manager; Bertram J. Abrahams, Con- ler. Standing from left to right: John J. Brophy, Materiel Manager; Harry J. Gray, Special Assistant to the President of Litton Industries, H. Richard Olsen, Production Manager.

Airtron's most recent activities include microwave nponents for a large share of this country's major sile needs, acquisition, capture, guidance and ground trol devices, as well as products on major aircraft part of installation and in the radar RT units. Air- supplies RF plumbing for the principal producers weather radar for commercial aircraft. The company lso called upon for flexible and rigid waveguide in microwave systems at missile launching sites, and is ducing components for intercontinental ballistics ch programs and airborne surveillance equipment.

s

Airtron Sales are at the $10 million per year level. npany officials project an increase of annual sales ume to $25 millions in the next three to five years.

David Ingalls estimates present industry sales of mi- wave plumbing used in Military applications at about 0 million per year. Sales of such equipment for mercial purposes, exclusive of installation, is now bably somewhat more than $50 millions. Ingalls eves that by 1960, military requirements will boost sales to $200 millions per year, due to increased nter measures activity and the large sizes of plumbing in early warning equipment.

ngalls says that it is difficult to estimate what the s of microwave relay equipment will be because of arcity of data; but a growth to $100 million a year by 1960 seems reasonable to him. This estimate, he adds, includes only the microwave portion of the relay, exclusive of tower and reflector sales.

Translating these figures into annual earnings, the estimates suggest that this industry will be directly employing well over 30,000 people by 1960. Airtron now employs between 900 and 1000 people.

The Merger

Harry Gray, head of Litton's components activities, recently observed: "The real significance of the Litton-Airtron merger is that the companies now offer a wider choice of microwave components, from tubes to antennas, plus a far greater capability for design and manufacture of one-of-a-kind components that the microwave engineer needs for his system, but cannot purchase off the shelf." And Litton President Charles B. Thornton, said when the Litton-Airtron merger was announced: "Since its founding in 1946, Airtron has established an outstanding reputation for research and development in the field of advanced microwave transmission components. . . . Microwave components have been, since the founding of our company, at the very core of our operations. We see an era ahead in which they will become even more important. Airtron will add materially to Litton Industries strength as a major electronics-based company." J.W.H.

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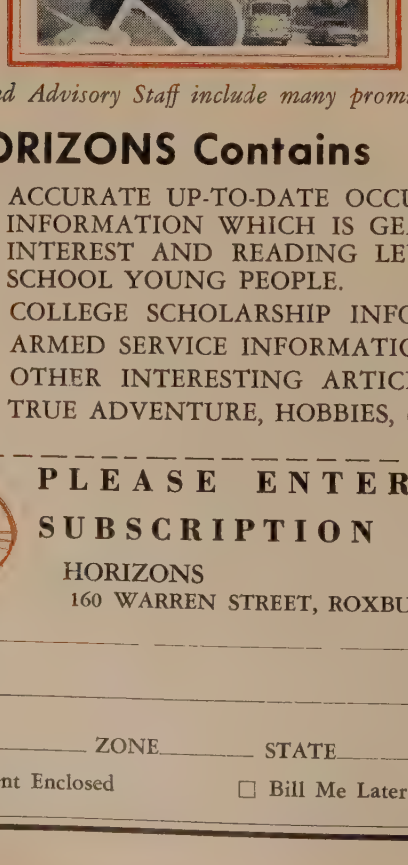

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CIRCLE READER SERVICE CARD 1

HE ANTENNA SLICE of the MICROWAVE USINESS

By CHARLES W. CREASER, JR.
VICE-PRESIDENT, D. S. KENNEDY CO.

Notes of the Industry

W. Creaser, Jr., well known throughout the microwave industry as "Charlie," is a resident of Scituate, Mass. In his work-a-day ld he is Vice President, Sales, for D. S. Kennedy & Co., Cohasset, Mass., designer and manufacturer of microwave antennas. His ne responsibilities are for the negotiation of contracts and the maintenance of engineering liaison with customers as well as the inistration of the sales department and the field engineering group. Charlie has been with Workshop Associates Division, briel Co., as Sales Manager, General Communication Co. as Project Engineer on radar beacons and with Harvey Radio Labora- es as Project Engineer on radar projects. His schools include Northeastern University and Lowell Institute. His society ac- ties include Institute of Radio Engineers, Armed Forces Communications and Electronic Association, and Aircraft Owners and Pilots Association.

N SOME QUARTERS the feeling exists that the antenna slice of the microwave business is much too great. This a reasonable thought on the part of project engineers o are responsible for systems development.

Unfortunately for the systems man, as his equipment omes larger and more complex, his antenna structure ewise follows along. Costs seem to increase by the square the complexity. Tracking antennas, for example, in- ase in cost by about the square as the size of the re- tor surface is doubled.

The project engineer has two incentives to restrict his enditures on the antenna phase of his system. In the place an antenna is a passive device. It apparently tributes what it is inherently able to contribute to the cess of the system and nothing more. The engineer likes to feel that the components he uses in his system are subject to his ability to control them. An antenna does not strike him as being this kind of a critter. Second, half the fun of his job comes with the pleasure of toying with circuits. Electronics is so flexible a science that it provides some of the most exciting possibilities for invention that ingenious minds have ever encountered. Engineers are inclined in some cases to believe that the ingenious circuit will substitute for characteristics supplied by the passive antenna.

The reflector we are talking about here is of a particular class generally called the large antenna. No arbitrary dividing line defines the class, but we can say in general that the peculiar characteristics of large antennas begin to appear at about twenty to thirty foot diameters. Tropospheric

scatter communications antennas generally are selected from three standard sizes, 28′, 60′ and 120′ diameter reflecting surfaces. Long distance radar antennas do not have any standardized sizes at present. They are generally upwards to 200′ high and several hundred feet long. Tracking antennas generally have a diameter of 60′ or 84′. Standard radio telescopes have been built in considerable quantity in 28′, 60′ and 84′ diameters. The compelling need for extremely large reflectors for radio telescopes is so great, however, that we have not come anywhere near reaching the limit of size. Radio telescopes up to 600′ in diameter are presently in the design stage and this has not been the limit of the radio astronomer's dream. Antennas for these applications are the ones that are tending to take a large slice of the microwave business.

Just how large a portion of the money for complex systems goes into the antenna portions is not known. An estimate of the total market for large antennas in 1957 was 12 million dollars. In the years 1958 through 1960 it is expected that the total market will approach 25,000,000 dollars a year. We have reason to believe that the expenditure for systems which will use large antennas may run to hundreds of millions. In view of these figures the cost of the large antenna may not be out of proportion to the system cost in view of the mission accomplished.

The mission of the large antenna goes back to some of its inherent characteristics. The new electronic systems require antennas of the highest possible gain and directivity. Each of these charactreistics are complementary, and both are increased with antenna size. None of the ingenious substitutes that have been suggested to minimize the size of antennas (such as masers and parametric amplifiers) really provide the characteristics that enable the large antenna to perform its mission. The large antenna is probably with us whether we like it or not. We can look upon masers and parametric amplifiers as devices that will enormously increase the efficiency of the modern complex electronic system, rather than as substitutes for antennas.

Perhaps of greater importance to the electronic industry than the existence of the large antenna is the effect that these giant structures have had upon the business organizations that supply them. At one time the antenna manufacturer was a job shop producer. Ordinary skills in the handling of metals were generally sufficient to enable him to turn out an acceptable product. The exception to this is the case of some kinds of small radar antennas such as those that are airborne. Sometimes these antennas must be very closely integrated with the design of the entire circuit. Sometimes the size of the antenna and mount as well as some of the complex gearing lend themselves to more specialized constructions, and these classes of antennas have tended to go out of the job shop into the specialized manufacturer's plant.

The large antenna producer also had to graduate beyond the job shop era. It became necessary to put a great deal more emphasis on both mechanical and electrical engineering. We are familiar with the fact, for example, that tre large antenna is much more susceptible to environment than smaller ones. Total bending moments from wind and ice loads become very great. The structure itself, as it becomes larger, has an increasing amount of self-weight, which adds to the mechanical engineering problems. Perhaps most significant of all, the majority of these large antennas have to be installed in odd-ball corners of the world. They are installed in the Arctic where winds reach severe hurricane velocities and blow upon structure that are already loaded with many inches if ice. Yet these antennas are expected to remain operational at all times. Not only has no way yet been found to de-ice these structures effectively, those methods that have been tried have presented extreme difficulties. For example, the use of heat to de-ice is only moderately successful, and, furthermore, the problem of getting fuel into the Arctic in sufficient quantities to maintain the heat required presents a difficult logistics problem. These antennas are sometimes installed in the desert where they must resist the effects of wind, sun, and sand. They are sometimes installed in the tropics where corrosion is the worst enemy.

In the field of electronic engineering the large antenna manufacturer has had to strive for super-accurate reflector surfaces, for increased efficiency of the reflecting surface, for better reflector illumination, for designs that achieve the best focal length to diameter ratio, for more efficient feed systems. The electronically scanned array shows great promise toward solving some of these problems including the mechanical problem of moving large reflectors at rapid speeds.

Not only has the designer and manufacturer of large antennas increased the size of his engineering department, he has also found it desirable to increase the amount of service that he can offer the customer. Erection facilities are an example of this. Large antennas are always shipped to the site in the knock-down form and assembled on the spot. Putting up one of these giants is a job for experts, especially if it is larger than the 28′ diameter units. The huge steel scatter and long distance radar antennas present erection problems similar to those encountered in the construction of large buildings. However, the requirements for surface accuracy and for precision surveying, as well as many of the difficulties encountered in the assembly make this a kind of work best suited to trained field crews rather than traditional construction workers. The erection of radio telescopes and tracking antennas is unique to the trade, and only trained antenna assembly crews are able to put one of these complex devices together. Manufacturers in the large antenna business tend to supply an even greater amount of field service facilities.

The large antenna business should also expect to have the opportunity to originate and promote many improvements in microwave propagation. They can perhaps cooperate very closely with the designers of transmitters and receivers. The maser and the parametric amplifier cited above are examples of improved receiver design. We do not yet have devices equivalent to these devices for transmitters.

The large antenna business enjoys one advantage in that it is a fairly stable industry. This is partly due to the fact that it embraces such a wide variety of equipments. We have mentioned scatter propagation, radar, radio telescopes, and tracking antenna systems as typical examples of the variety. To these we could add not only related devices such as solar furnaces, but also ingenious uses that are constantly coming along. Among the latter is a recent proposal to use a large antenna to beam a usable amount of electric power into space to be used by orbiting satellites.

We can expect the large antenna business to continue to enjoy a sizable slice of the microwave business if it will use its own unique abilities to expand its own research and development.

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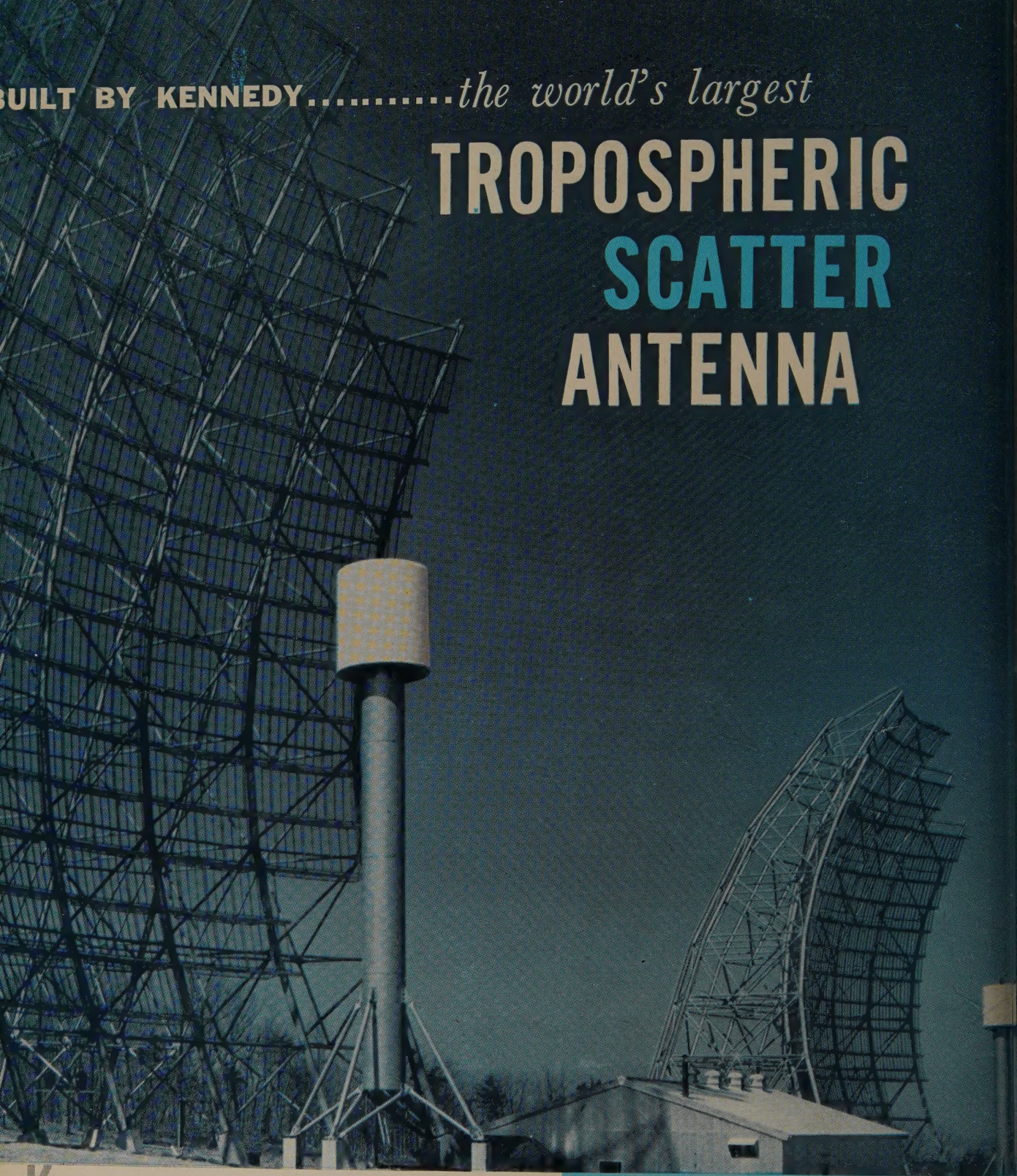

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